A

# TREATISE

ON

# PLOUGHS

AND

# WHEEL CARRIAGES,

ILLUSTRATED BY PLATES,

BY

JAMES SMALL PLOUGH AND CART WRIGHT, formerly at Blackadder-mount, now at Rose-bank, near Foord, Mid Lothian.

——— I boldly recommend a plough introduced into Scotland about twelve years ago, by JAMES SMALL at Blackadder-mount, Berwickshire, which is now in great request. This plough may be considered as a capital improvement.

LORD KAIMES' Gentleman Farmer.

EDINBURGH:

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M.DCC.LXXXIV.

TO

ALEXANDER RENTON

OF LAMERTON, ESQ;

THIS

TREATISE

IS

MOST HUMBLY AND RESPECTFULLY

INSCRIBED,

AS A TESTIMONY OF RESPECT

AND GRATITUDE

FOR THAT

COUNTENANCE AND PROTECTION

SO LONG AFFORDED

HIS

MUCH OBLIGED SERVANT

JAMES SMALL.

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INTRO-

# INTRODUCTION.

THE Plough is an inſtrument of ſuch importance in agriculture, that, in all ages, it has held the firſt place among the implements of that art; nor is there any nation mentioned in hiſtory, who have attempted to cultivate the ground without it, excepting ſome Barbarians, deſtitute of every art and ſcience. And even theſe have uſed ſomething equivalent, ſome turning up the ground with the horns of oxen, and ſome with other things equally unfit. Theſe rude and barbarous attempts only ſhow the great uſefulneſs of the inſtrument of which I propoſe to treat.

Though many of the ancient nations underſtood agriculture very well, and had invented ploughs of different forms, all of them ſeem to be inferior to ſome of thoſe lately introduced among us. Although the ancients had made great progreſs in the arts of life, their knowledge of mechanics was more imperfect, and leſs diffuſed, than among us, and therefore their improvements will not bear a compariſon with thoſe which have taken place within theſe two laſt centuries.

It is ſomewhat ſtrange, that, amidſt all the improvements which have been made during this period, the plough ſhould have remained almoſt in the ſame ſtate, till within theſe laſt fifty years. The truth is, that it has been neglected

neglected by those persons who have turned their attention to machines, as a rude tool, unworthy of their attention. Such persons imagined that any thing could do for the clumsy operation of turning up the ground, and that there could be no nicety in a work which was successfully performed by the ignorant peasants. Other persons have imagined, that it is impossible to explain the principles by which the plough performs its work. If this be true, we must act at random in making this important instrument, without knowing whether we are right or wrong, except by the event; and if the plough should not answer our purpose, our attempts to amend it must be without rule, and as liable to error as before.

Both these opinions are very erroneous, and the maintaining them would be productive of very bad consequences, by checking the improvement of agriculture: For, although our knowledge of the nature of plants, and of the manner of promoting their growth, should improve ever so much, and the husbandman should know, that, if his ground were so and so dressed, his crops would be improved, yet, if the imperfection of the plough be so great, that this dressing cannot be given without a very great expence, the knowledge of the husbandman is rendered almost useless.

The plough is so far from being a rude and despisable tool, that it is a machine of very ingenious contrivance, even in

the rudeſt form in which it appears in this country. Several circumſtances in the conſtruction, even of our oldeſt ploughs, are far from being obvious, and yet the neglect of them would have rendered the ploughs much leſs fit for their work than they are. The circumſtances, upon which the goodneſs of a plough depends, are both many, and difficult to be diſcovered; and it requires both great ingenuity and great experience to determine that form of a plough which will enable it to perform its work in the beſt manner, and with the leaſt labour poſſible. So that, whether we conſider the importance of the plough, or the great nicety of its conſtruction, it is a ſubject very fit for exerciſing the genius of the moſt eminent

mechanics

mechanics and philoſophers in Europe.

On the other hand, this is not a taſk which exceeds the powers of our underſtanding; and it is not impoſſible to explain the principles upon which the plough acts in performing its work; and, conſequently, to determine that form which ſhall do this in the beſt manner. Let the huſbandmen once be agreed as to the ſtate in which the ground ſhould be left by the plough. The taſk which it is to perform is now a fixed thing, and there muſt be one manner of performing it, which is better than any other. Now, it is certain that a plough may be made which ſhall perform a taſk in any manner whatever, and therefore in this beſt manner.

It

It would be great preſumption in me, if I ſhould pretend to give perfect inſtruction in a ſubject which I have ſaid is fit for exerciſing the greateſt genius. My ſituation in life has deprived me of many advantages of theoretical learning.

But, on the other hand, it has given me a good deal of experience, both as a huſbandman, and an artificer. This advantage appears to me conſiderable, and not very common, and has engaged me to turn my attention to the improvement of the plough more than many others of my profeſſion. Some of my views were much approved of by gentlemen of great judgement and experience, which encouraged me to beſtow ſtill more attention upon the ſubject,

and to put immediately in practice every alteration which I thought would be an improvement. It is to ſuch encouragements, and the opportunities thereby given me for improving my ploughs, that I am indebted for the good character which they have given me, both in this neighbourhood and at a diſtance.

The ſame gentlemen who have encouraged my attempts to improve the plough, have alſo flattered me with the hopes that I would do a ſervice to ſociety, if I ſhould make public my notions upon this ſubject. I have therefore ſet them forth, ſuch as they are, with ſome degree of truſt that my ſentiments will be found pretty juſt, and with almoſt a certain confidence, that ploughs, made

ac-

according to the directions which I have given, will be found to perform their work in an agreeable manner. If any person of skill shall think it worth his while to correct any mistakes into which I have fallen, he will deserve well of the Public, and will have my particular thanks for the opportunity which he will thereby give me of improving in my profession. The chief merit which I claim in the following sheets is this, that I have given directions by which any sensible workman may be enabled to make a plough on my principles, without being reduced to the necessity of copying, and that those directions are such as will enable him to make a plough on any principles whatever. All that is necessary to be known

is the ſtate in which the ground is to be left by the plough. My directions enable the workman to make a plough which ſhall leave it in that ſtate. So that, whether my principles are good or not, my directions for making a plough loſe nothing of their value.

I hope that a candid and good natured Public will receive, with indulgence, my endeavours to be uſeful, and will pardon thoſe defects which ariſe either from my ſituation, or from my want of talents. I am too ſenſible of the reſpect which is due to the Public, to be wanting in care and attention.

## Of the Action of a Plough in general.

IN ploughing three things are performed. A ſlice of earth is cut off from the general maſs. This ſlice is removed ſome inches to one ſide. It is ſo turned, that it may expoſe a new ſurface to the air, and that what was formerly uppermoſt may now be buried. To the performance of theſe things, the conſtruction of the plough muſt be adapted, and the work muſt be performed with as little labour to the cattle, and to the ploughman, as poſſible; and the ploughman muſt have it in his power to vary at pleaſure the depth, wideth, and poſition of the fur-

row.

row. The firſt of theſe actions is performed by the coulter, the ſecond and third by the ſock and mouldboard jointly. Theſe are to be conſidered in order.

*Of the Coulter.*

The coulter muſt be conſidered as a cutting inſtrument, oppoſed to great and various reſiſtances. It muſt be ſharp, that it may cut the more eaſily, and ſtrong, that it may not be broken or bent. Theſe properties cannot be united, unleſs it is thin and broad. The giving it great ſtrength, by means of great thickneſs, expoſes it to more reſiſtance than is neceſſary; whereas, increaſing the breadth of the coulter diminiſhes the reſiſtance, by making it a ſharper wedge.

The

The dimenſions of the coulter may be as follows: An eighth of an inch thickneſs at the edge, and an inch thick at the back, for a three horſe plough, or ſeven-eighths for a two horſe plough. The web may be three inches broad at the broadeſt, and taper from a foot down all the way to the point. The thickneſs of the back may taper alſo. The length is about twenty inches. It may have a little rounding on the furrow ſide, from the edge to the middle, and ſhould be flat on the land ſide.

The operation of the coulter depends greatly upon its poſition. The plough may be conſidered as a ſort of wedge, employed to remove the earth both from the land ſide and from the bottom of the furrow. The land ſide and bottom of

of the furrow, are, each of them, to be kept ſtraight. This circumſtance, as we ſhall ſee more fully afterwards, require that the land ſide and ſole of the plough be plane ſurfaces. The coulter therefore muſt be placed in the plane of the land ſide of the plough. By this means, the cut which it makes forms the land ſide of the furrow, to which the plough is afterwards preſſed, by the reſiſtance acting upon the furrow ſide of the ſock and mouldboard. For the ſame reaſon, it appears proper to me, that the land ſide of the coulter ſhould be in the plane of the land ſide of the plough, and that its whole thickneſs ſhould be on the furrow ſide. When the plane of the coulter has any other poſition, there will always be a force acting

acting on the plough, tending to change its direction. This muſt be oppoſed by the continual influence of the ploughman, or by the form of ſome other part of the plough, which ſhall give it a contrary tendency. The firſt method is evidently improper. The ſecond is no leſs ſo, becauſe, though theſe contrary tendencies may balance each other, they both increaſe the labour of the cattle. It may be objected to this reaſoning, that by making the land ſide of the coulter in the ſame plane with the land ſide of the plough, or parallel to it, the coulter itſelf will be preſſed in towards the land, by the reſiſtance of its furrow ſide. This is true, but is, in general, compenſated by the firmneſs of the ground on the

land

land ſide. When the edge of the coulter ſtrikes a ſtone directly, the ſtone, although driven ſtraight forward, moves to the furrow ſide, where it is leaſt reſiſted. But if the coulter has its edge exactly in the middle of its thickneſs, and ſtrikes a ſtone with its land ſide, the plough muſt be thrown from the land, becauſe the ſtone cannot be preſſed much farther into the firm ground.

In fitting the coulter into the beam, the mortiſe muſt be made parallel to the plane in which the plough moves, and not pointing to the furrow ſide, as is much practiſed; for this practice always gives the plough a tendency to turn off from the land. The poſition which I here recommend for the edge of the coulter, cauſes it to co-operate

with

with the ſock and mould-board, in removing the earth, which is an advantage not to be deſpiſed.

The loſs ſuſtained by the wrong poſition of the coulter, does not very ſenſibly appear in a plough which is drawn by the beam, projecting ſo much before it; but would be very diſtinctly felt, if the draft chain were faſtened to the coulter itſelf. In this caſe, it would be found that it will be hardly poſſible to keep it in its proper direction.

Another thing to be taken notice of with reſpect to the poſition of the coulter, is its rake, or inclination forwards. It would ſeem, at firſt ſight, that the edge of the coulter ſhould be upright; but experience, perhaps without any principle, has directed us to point it

forward below. Some principles are, in this cafe, perfectly conformable to experience. In the firft place, the inclination of the coulter makes it cut the earth more eafily ; for, it is well known, that, in all operations with cutting inftruments, the work is more eafily performed when the edge of the inftrument is placed oblique to the direction of its motion. I cannot give a better inftance, than the operation of fhaving, where the refiftances in the different pofitions of the edge of the rafor are moft eafily diftinguifhed. Some think, that a lofs is fuftained by the point of the coulter cutting the furrow fo much below, before it is cut above. But it may be eafily fhown to fuch perfons, that no lofs is fuftained ; but, on the contrary,

a

a real advantage is gained. When the point of the coulter projects much below, it cuts the ground partly upwards, in which direction its cohesion is most easily overcome. Also, when the coulter comes to tough roots, which it does not cut at the first touch, it presses forward below them, strains, and tears them with the increased force of a wedge, and at last breaks them, with much greater ease than if its edge were upright. By this means too a very tough root is made to slide up along the coulter, till it comes to that part of its edge, which is not much employed in cutting the furrow, and is therefore sharper than the rest. Thus, the roots being cut by different parts of the coulter, as they differ in strength,

and

and being, in general, thrown up to its top, the coulter is cleared of them in that part chiefly employed in cutting the furrow.

But if the edge of the coulter were perpendicular, it would carry along with it the roots which it does not cut, which would greatly increaſe the reſiſtance which it meets with, and would frequently choke the plough, and ſtop its motion. In like manner, when the coulter comes to a ſtone, it makes it riſe upwards, in which direction it is more eaſily moved; whereas, if the edge were perpendicular, it behoved to force it ſtraight forward.

Another advantage attending this inclination of the coulter, is, that it tends to keep the plough in the ground.

That ſome force is neceſſary for this purpoſe will eaſily appear. In the manner in which cattle are commonly yoked, the line of draught makes an angle of about 24 degrees with the ſole of the plough, or bottom of the furrow. The tendency of the draught therefore, is always to pull the plough out of the ground; and if the edge of the coulter were upright, it would give no oppoſition to this tendency. Nay, even if the coulter were pointed 24 degrees forward, it would not have any effect. It muſt therefore project ſtill more, in order that the reſiſtance upon its upper edge may co-operate with the reſt of the plough, in oppoſing this general effect of the aſcent of the line of draught, This additional projection

of

of the coulter is the more neceſſary, for the purpoſe of keeping the plough in the ground; becauſe, as we ſhall ſee afterwards, there are other circumſtances which alſo tend to throw the plough out of the ground.

I would therefore recommend an inclination, or rake, of about 45 degrees, as the moſt proper, and the moſt conducive, to all the good purpoſes hitherto mentioned. The propriety of this poſition will be illuſtrated by conſidering figure 1ſt. Let A H repreſent the line of draught, making an angle of 24 degrees, with L M, the bottom of the furrow. This line of draught is ſuppoſed to paſs through the centre of effort of the plough. Let it cut the edge of the coulter in N. This point will

will be found to be about 4 or 5 inches from the bottom of the furrow, though N draw C D perpendicular to A H I. Then, if the edge E F of the coulter makes an angle of about 45 degrees with L M, it will make an angle of about 20 degrees with C D. There being nearly the ſame quantity of earth cut by the part below N, as there is cut by the part above N, the coulter will be equally preſſed on each ſide of the line of draught, and will, in this reſpect, have no tendency to turn the plough out of the ground, nor into it. This poſition will therefore be the moſt proper, when the ſock is at the longeſt, and will admit of being changed, ſo as to bring the point of the coulter near to the ſock; when this is ſhorter, while the

the ſock is of ſuch a length as to make the coulter more inclined than C D, the coulter will always help to keep the plough in the ground.

The next thing to be conſidered in the poſition of the coulter, reſpects its fitneſs for clearing, or freeing, the part of the plough which follows it in the furrow.

The defects of the common form of the land ſide of the plough, and of the poſition of the coulter correſponding to it, are very ſenſible, both when we uſe the long practiſed ſpear ſock, and plain mouldboard; and alſo when we uſe the more modern feathered ſock, and curved mouldboard. Theſe defects have been diſtinctly ſeen by the actual compariſon with a plough of a more per-

perfect conſtruction, and may be ſufficiently underſtood, by attending to the deſcription which will now be given of this improved plough.

The plough, as has been already obſerved, may be conſidered partly as a cutting inſtrument, of which the coulter forms the edge. It is not employed in cutting the earth, and ſeparating it on both ſides, in which caſe it would rather reſemble a cleaving inſtrument; but it is employed in cutting a ſmall ſlice from the firm ground, on the left hand, and removing it to a certain diſtance to the right hand. The chief reſiſtance being therefore exerted on the furrow ſide of the plough, the plough is preſſed to the firm ground on the left hand. By this means the land ſide of

the plough becomes the director of its motion, and therefore, in the perfect ſtate of the inſtrument, ſhould perform no other part of the work. This conſideration ſhows at once that the land ſide of a plough ſhould be a flat or plane ſurface. If it has any other form, being ſtrongly preſſed to the firm ground, its projecting parts muſt ſink into it, and the plough cannot advance without continually tearing off the earth with its projecting parts; which earth muſt tumble in between the coulter and ſheath, or into any hollow in the land ſide of the plough, and, collecting gradually there, will both obſtruct its motion, and turn it from the land. Here, without any further argument, appears the great imperfection of the Scotch

plough

plough, as uſually made; and the advantage which muſt attend the covering the hollow between the head, ſheath, and ſtilt, with boards, to reduce it to a flat ſurface.

In the next place, this flat ſurfaoe, which forms the land ſide of the plough, muſt be in the direction of the plough's motion; that is to ſay, a ſtraight line, drawn from the heel of the plough to the point to which the cattle are yoked, muſt touch the land ſide of the plough. If the ſurface of the land ſide of the plough, and the edge of the coulter, points to the right hand of the fore end of the beam, the plough will be thrown continually from the land, by the reſiſtance which it meets with on that ſide, the contrary effect will be produced if

this ſurface points to the left of the fore end of the beam: but when the land ſide of the plough, and the line of draught are in the ſame plane, the plough will go ſmoothly and ſteadily, without any effort of the ploughman.

This conſideration leads us to attend a little to the form of the beam. The mortiſe, for receiving the coulter, muſt be in the middle of the thickneſs of the beam, in order to give the greateſt ſtrength. The ſame may be ſaid of the mortiſe in the ſtilt for receiving the beam. The coulter muſt be ſet to the left of the land ſide of the plough, nearly the thickneſs of its back, by which means the earth, which is puſhed a little to the right hand by the thickneſs of the coulter, will be received on the edge

of

of the ſheath and mould-board. Theſe conditions cannot be obtained, if the beam is equally tapered on the land and furrow ſides, as is uſually practiſed. For, in this caſe, the coulter will have its upper part removed to the right hand of the land ſide of the plough by half the thickneſs of the beam. This is accordingly the caſe in the uſual conſtruction of the plough; and this defect is attempted to be remedied, by placing the plane of the coulter, not upright, but pointing with its lower end to the land, and projecting beyond the land ſide of the plough near five inches, as in fig. 3, 4, and 9. which repreſent a croſs ſection of the plough at the heel, ſeen from the point of the beam. I ſhall firſt deſcribe the conſtruction,

which appears to me to be the moſt proper, and then ſhow its advantages, by comparing it with the common form.

The beam ſhould be $4\frac{1}{4}$ or $4\frac{1}{2}$ thick between the coulter-hole, and the hindermoſt ſide of the ſheath, and it ſhould be $4\frac{3}{4}$ or 5 deep at the ſame place. At the fore end, the thickneſs ſhould be $2\frac{1}{4}$, and the depth $3\frac{1}{2}$. It may have a curve of 6 inches up and down, which the ploughmen call the redde of the plough.

Inſtead of tapering the beam equally on both ſides from the place of the coulter, as repreſented in fig. 2. No. 2. I make the beam ſtraight on the furrow-ſide, as in fig. 2. No. 1. and taper it only on the land ſide, both ways from the place of the coulter. The taper backwards

backwards to the hindermoſt ſide of the ſheath, ſhould be ſuch, that, when a ruler is laid to the ſide in that place, it will project 2½ inches to the left of the fore end of the beam. A B in this figure is the plane of the land ſide of the plough, which, by this way of tapering, paſſes very near the middle of the thickeſt part of the beam. By this method, the coulter-mortiſe is brought over to the land ſide, half of the taper given to the beam. But as this is not ſufficient for bringing the coulter into the poſition formerly recommended, I give the coulter a knee, or ſet of 2 inches, as repreſented in fig. 5. Thus, the coulter may be ſet ſo as to make it cut in the beſt manner, and yet be in the middle of the beam. The ſheath is alſo mortiſed

mortiſed nearly into the middle of the beam, but has a ſhoulder to the land ſide of ½ an inch. This makes the land ſide of the ſheath juſt touch the line A B (fig. 2. No. 1.) drawn from the land ſide of the fore end of the beam to the land ſide of its other end, and thus the land ſides of the fore end of the beam, of the ſheath, and of the ſtilt, are all in one plane ſurface. This cauſes the coulter to clear completely the part of the plough which follows it in the furrow. But when the beam is made in the uſual manner, as in fig. 2. No. 2. the coulter does not clear the plough in all the parts of the land ſide. For, in this caſe, the line O K (fig. 4.) will repreſent the land ſide of the ſheath, mortiſed into the middle of the beam, and N K will repre-

ſent

ſent the land ſide of the ſtilt, (the point N of fig. 4. correſponding with V in fig. 2. No. 2.) and the angle OKN will be the twiſt of the land ſide of the plough, (the ſpace ON being about 1½ inches,) by which it appears, that the land ſide of this plough will point to the right of the fore end of the beam, which will give the plough a tendency to quit the land, or to turn into the furrow. In this conſtruction, the coulter, being put ſlanting into the beam, ſo as to project to the land ſide about 5 inches below, does not clear the plough equally in all its parts. For the plane of the coulter interſects the plane of the ſheath about 2½ inches below the beam, and the plane of the ſtilt much lower. By this means, although the lower part of

the plough is more than ſufficiently cleared, the upper part is not cleared at all. Accordingly, it may be obſerved, that in ploughs of this conſtruction, the upper part of the plateing on the land ſide is more worn away than the lower, although it moves in looſer earth. It is ſtrongly preſſed to the firm land, while the parts near the ſole do not touch it, or touch it after the upper parts have been bruiſed together.

All theſe circumſtances conſidered together, ſhow that a plough of this conſtruction is in a ſtate of continual twiſting, by the very unequal preſſure of its different parts to the land. This muſt be varied by changing the poſition of the coulter, ſo as to point its lower end more or leſs to the land; whereas, by

making

making the land ſide of the plough in the direction of its motion, it is kept equally preſſed in all its parts, and therefore ſinks leſs in any one part, which makes it more ſteady in its motion, and more eaſily drawn, and the coulter, being kneed and placed as directed, frees the plough completely and equally in all its parts.

This may be further illuſtrated by fig. 6. which is adapted to a plough conſtructed as in fig. 4.

M N is a line drawn through the very point of the coulter, and hindermoſt end of the land ſide. H P is a line drawn through the edge of the coulter, and hindermoſt end of the land ſide, one foot up from the ſole, and N R is the line which is parallel

to the direction of the plough's motion at a medium. The other two, H P and M N, are nearly equidistant on each side of N R. Now, although this is the line which ought to be in the direction of the plough's motion at all times, it cannot be so in this construction, except at one particular depth, because, with every different depth of furrow, the plough makes different degrees of land, on account of the coulter projecting obliquely to the land side.

These defects of the common construction are sometimes not observed, on account of other defects of the instrument, and they are thought to be compensated by the greater quantity of work which the plough *seems* to perform, by having the coulter turned so much

much to the land. But this is a deceit, and the quantity of real work is not increased by this position of the coulter. For, by the point of the coulter being so much to the land side of the sock, a good part of the slice cut by the coulter is not raised by the sock, but is broken on the corner of the sock and sheath, and, falling in between the coulter and sock, obstructs the motion of the plough, and even throws it out of the ground. This obstruction is most distinctly perceived in the plough with a feathered sock. The furrow strikes on the land side of the sock, at its first rise, when it would, at any rate, press most upon what is below it. Also, by this pressing on the land side, both of the spear and feather sock, it tends to turn

All these inconveniencies seem to be removed in the construction here recommended. The point of the coulter is placed about two or three inches before the point of the sock, and within half an inch or an inch of the plane of the sole, and the edge, with the land side, projects about half an inch or an inch beyond the land side of the plough; so that the coulter is about as much beyond the plane of the land side, as the point of the sock is below the plane of the sole.

This construction was not relished by some persons who had been accustomed to the common form; but, when tried, appeared as much preferable as I have described it. In this construction, the advancing of the coulter so far before

before the sock, causes it to cut the furrow so much the more forward, before it is raised by the back of the sock; but, by the great inclination of the coulter, the furrow is not so much cut above when it begins to rise on the sock, as its forward position would make one expect. The furrow is therefore soonest cut in the very place where it is to be soonest raised. If the coulter were placed as much behind the sock as it is here advanced before it, the ground would be raised before it is cut, which would increase the labour of the cattle, by causing a shorter, or more sudden turn of the furrow. But here, the furrow being cut at some distance before the sock, is more easily turned, or twisted by it.

It has been ſaid, that the coulter thus far advanced before the ſock, is more apt to ſtrike on a ſtone, without having any ſupport from the ſock, which, in this caſe, receives no part of the ſhock, and then the coulter is more liable to be bent out of its poſition. But, in compenſation of this, it may be obſerved, that although the coulter is thus more liable to be bent, it does not tend ſo much to break the plough, which will endure more ſtrain from a ſtroke on the coulter than from a ſtroke on the ſock. Beſides, when the coulter is no more advanced than the ſock, and placed at the uſual diſtance on the land ſide, it is as liable to be hit by a ſtone, as in the conſtruction now recommended, and has no ſupport from the ſock, and the ſock

sock may, at the same time, receive a shock from the same, or another stone. The chance of these shocks is therefore double; and if the stone is struck by both at once, it is not turned aside, as it would be if struck only by one of them, but must be carried forward before the plough, through the firm ground. For all these reasons, the construction is still preferable; but, as the coulter is liable to these shocks, I have strengthened it by a stay of iron, represented by H F, fig. 1. This is on the land side of the coulter, and turns on a bolt through the coulter at F, and passes through the eye of a bolt I, which passes through the beam. The upper part, H I of the stay is screwed, and the nut which turns on it supports the stay, and

en-

enables us to raiſe or lower the coulter at pleaſure. This ſtay alſo produces another good effect, by preventing the ſtubble from being preſſed up into the angle formed by the coulter and beam, from which it is very troubleſome to diſlodge it. I may here obſerve, that it is not a good practice for the ploughman to puſh the ſtubble which gathers on the plough to the furrow ſide. It ſhould be puſhed to the land ſide, ſo that it would fall into the track of the plough, and be buried; whereas, by puſhing it to the furrow ſide, it is apt to lye above. It is alſo eaſier for the ploughman, with his right hand, to puſh it to the land ſide.

On the whole, this poſition of the coulter, a little to the left of the land

ſide

side of the plough, and parallel to it, causes the coulter, by its thickness behind, to bring the furrow exactly on the edge of the sheath and mouldboard. No earth falls in between the plough and firm land in wet or loose soils; none strikes on the edge of the sheath and mouldboard in hard soils, but the furrow slice takes a regular rise, with its corner right with the land side of the sock. No roots can pass between the coulter and sock without being cut, and the corner is kept in the furrow, and turned up. And, *lastly*, the whole land side of the plough being equally pressed to the firm ground, the pressure on no part is very great, and the plough is prevented from running into the firm ground by any sudden strain on the opposite side.

The

4. In these two figures, it appears that the upper and under corners, E G, of the furrow slice, made by the plough, fig. 5. are square, whereas the two corners, R and N of the slice made by the plough of fig. 4. are about 13 degrees above the square. In order that the furrow may stand in this position, it must either lean upon the former furrow, or it must be supported by loose earth, which tumbles in below it, and fills up the vacancy represented by H G K of fig. 8. or P R S fig. 9. It is easy to see, that the vacancy of fig. 8. is easier made up than the other.

Although this position of the furrow slice is not always required, it being sometimes thought proper to leave it standing upon its edge G H, it is plain, that

that even in this caſe the plough of fig. 5. has the advantage ; for the furrow ſlice made by it will ſtand upright, whereas that made by the plough fig. 4. will lean to the ſpace left by the plough, and it will hardly be poſſible to prevent it from falling back into its former poſition, eſpecially in ploughing with a ſhallow and broad furrow.

*Laſtly*, It appears that the plough of fig. 5. will leave the ploughed ground with a flater toped furrow than the plough of fig. 4. which is alſo thought an advantage by the moſt intelligent farmers.

The reader will obſerve, that I have always ſuppoſed that the land ſide of the plough is kept perpendicular. It is a very uſual practice to lean the plough

over to the left, or land ſide; but I do not approve of this practice, becauſe it leaves the bottom of the furrow higher on the furrow ſide, and this leaves ſome of the earth not raiſed, and the furrow turned over has not ſo full a ſhoulder. It is in ſome degree to make amends for this, that the coulter is ſet ſo far to the land below. But the practice ſhould be laid aſide, and then this improper poſition of the coulter will not be neceſſary.

Thus it appears, that whether we conſider the working of the plough, or the work which it performs, the plough of fig. 5. having its land ſide a plane ſurface, ſtanding in the direction of the plough's motion, with the coulter parallel to it, is, in every reſpect, prefer-

able

able to the plough fig. 4. which has its land ſide twiſted, and the point of its coulter turned ſo far into the land.

## *Of the Sole and Sock of the Feather Sock Plough.*

In the make of the ſole of this plough, three things are to be conſidered.

*Firſt*, The form of the land ſide ſole, or head, and the poſition of the ſock, for keeping the plough at the proper depth and breadth of the furrow, and ſolid in its motion.

*Secondly*, The breadth from the out land ſide ſole, to the out ſide of the mouldboard ſole behind, and the inclination and height of the mouldboard ſole, with reſpect to the land ſide ſole.

*Thirdly*, The proper breadth and inclination of the feather, correſponding to the breadth and inclination of the ſole.

*Firſt* then, with reſpect to the form of the ſole, and the poſition of the ſock, which are moſt proper for keeping the plough at a proper depth, and ſolid in its motion. This is a point of the greateſt difficulty in the conſtruction of the plough, and therefore muſt be minutely conſidered.

Let L M, fig. 1. repreſent the bottom of the furrow. As the plough advances, its fore parts and furrow ſides are expoſed to reſiſtances. The coulter is preſſed down by the earth which it is cutting. The ſock is preſſed down, and alſo a little to the left

by

by the earth which it is raiſing. The fore part of the mouldboard is preſſed down, and alſo to the left by the earth which it is partly raiſing, partly ſhifting to the right, and partly turning over. The hindermoſt part of the mouldboard is preſſed to the left by the earth which it is forcing to the right, and is alſo preſſed upwards by the earth which it is turning over. Theſe reſiſtances, taken together, give to the plough a tendency to thruſt the point of the irons deeper into the ground, and to twiſt the point of the ſock downwards to the right, and the hindermoſt part of the mouldboard upwards to the left.

If, therefore, the plough were drawn forward, by a rope faſtened to the point of the ſock, and level with the bottom

of

of the furrow, the plough would infallibly ſink at the point, and riſe at the heel; and, at the ſame time, twiſt over to the furrow ſide. With ſuch a draught, therefore, the ploughman muſt continually preſs upon the left ſtilt. But the plough is not drawn in the manner here deſcribed, but in an oblique direction K A, from the bridle bolt K to the point A, where the draught ropes paſs through the horſes backband. This direction of the draught tends to pull the plough out of the ground. That this may not happen, the draught muſt be ſo placed as juſt to balance the plough's tendency to go deeper. Suppoſe H A to be the direction of draught which is exactly proper for this purpoſe. Produce the line A H backwards, till it

meet

meet the coulter in N, the ſock in O, and the ſole in I. Every perſon ſkilled in the principles of mechaniſm knows, that the motion of the plough will be the ſame, whether the draught rope is fixed at H, N, O, or I, as the direction I H A is the direction of the draught, ſo A H I is the direction of the reſiſtance, the labour of the cattle being the ſame as if the plough were not reſiſted by the earth at all, but were kept back by a rope faſtened at H N O, or I, and pulling in the direction H I. There will, therefore, be ſome point in the plough, between H and I, where all the reſiſtances may be ſuppoſed to be united. We ſhall, for the future, call this point the centre, or point of reſiſtance. We may alſo call it the centre of action, be-

becaufe the action of every part of the plough is directly oppofed, and is equal to the refiftance which that part overcomes.

If we confider the preffure on the hindermoft parts of the mouldboard, which tends to raife it up, we fhall find that the plough will not fwim fair, as the ploughmen exprefs it, but will rife at the heel. This effect will be ftill farther increafed, if the point of the coulter or fock meet with any uncommon obftacle. In fuch a cafe, if the draught rope is fixed at the centre of action, or any where behind it, the heel of the plough will always rife, and the plough will twift downward on the furrow fide. But if the draught rope is fixed at H, this rife of the heel will ftop in time,

be-

becaufe, by this means, the point of the beam is depreffed, and the line of draught comes to make a greater angle with the level of the furrow. When this happens, the draught again raifes the point of the beam, and finks the heel of the plough. It is evident, however, that the motion of a plough trimmed in this manner, will be very hobbling and irregular.

This defect is removed by a very fimple contrivance; namely, by fixing the draught-rope to fome point K, below the ftraight line A I, which paffes thro' the centre of action. By this means, the plough becomes a fort of lever, of which the centre of action is the fulcrum. The lever is pulled upward at K, and, being fupported at the fulcrum,

the hinder part of it is preſſed down, and the heel of the plough M is kept firm in the bottom of the furrow. This makes the plough go ſolid, as the ploughmen expreſs it, and neither go deeper into the ground, nor riſe out of it. This the ploughmen call having a right hold of the ground.

It is eaſy to ſee, that this circumſtance in the trim of a plough is of the utmoſt conſequence to the perfection of the inſtrument. We ſee alſo, in general, that the plough may get more or leſs hold, by raiſing or lowering the point K, to which the draught-rope is fixed. This is the uſe of the ſhifting pieces of the bridle fixed to the fore end of the beam, which put it in the power of the ploughman, to trim

or

or temper the plough to his mind. Making the bridle bolt too low, both causes the plough to rise out of the ground before, and causes the heel to press more on the bottom of the furrow than is necessary, and also causes the hindermost and upper part of the mouldboard to press too hard on the earth, at quitting it, which is productive of bad effects in moist clay soils, by casting the earth into a solid clod. No more should be done than what is just necessary to make the plough go steady, by keeping the heel gently pressing on the bottom of the furrow.

From the account here given of the operation of the plough, and the various resistances to which it is exposed, it is easy to infer, that the proper place of

of the point of draught at the fore end of the beam, muſt depend on the form of the plough, both with reſpect to its ſock and mouldboard. A plough, of which the ſheath has little inclination or rake forwards, being leſs preſſed down before, will require the point of draught to be higher than a plough of another make. Thus it appears, that when a plough is already made, its hold may be regulated by the place of the point of draught.

On the other hand, a plough, whoſe point of draught is fixed, or cannot be ſufficiently changed, may have its hold regulated by the make of its ſock and mouldboard; for theſe two things, the place of the point of draught, and the make of the plough, have a mutual de-

pendence,

pendence, and neceſſary connection with each other. This laſt method of regulating the hold of a plough depends on the form and poſition both of the ſock and mouldboard. Pointing the ſock downward will increaſe the hold of the plough, and raiſing its point will diminiſh it. Alſo, by inclining the ſheath much forward below, we increaſe the hold of the plough, and by making the ſheath more upright, we diminiſh it. Thus a plough may have hold both by the ſock, and by the make of the plough. It is plain, therefore, that theſe may be ſo adjuſted as to give the plough a proper hold on the whole, and a plough, which has too much or too little hold by its make, may be brought to a right temper, by giving it leſs or more

more hold by the ſock. But it is plain, that although the exceſs or want of hold by the make, may be balanced or corrected by a want or exceſs of hold by the ſock, and thus the plough be made to have, on the whole, a proper hold; yet this expoſes the plough to oppoſite ſtrains, and increaſes the labour of the cattle, and that the plough will be more perfect, when the hold by the ſock and by the make both agree. This will alſo be attended with the advantage of making the upper part of the ſock and the mouldboard of one regular twiſt, which will give the eaſieſt turn to the furrow, and leave it in the beſt ſtate.

It would appear, that the beſt poſition of the ſock is to have its under

ſurface even with the plane of the ſole. But experience teaches us, that a plough goes more ſteadily when the ſock projects a little below. The reaſon ſeems to be this: When the ſock and ſole are in one plane, and the point of the ſock meets a ſmall ſtone, it cannot get below it, becauſe the ſole is then on the firm ground. The plough muſt therefore paſs over this ſtone, and loſe part of its hold. Or, if the reſiſtance of the ſtone againſt the upper part of the ſock forces down the point, the heel muſt immediately riſe; whereas, when there is a ſmall projection downward of the ſock, a little hollow is left under the fore part of the ſole of the plough, which allows it to ſink a little deeper, and thus throw up the ſtone, and, at the ſame time,

time, does not neceſſarily force up the heel. All this may be done with a ſock of a regular twiſt, and proper length and ſhape on its upper ſide, by making the point of the ſock about five eighths of an inch below the plane of the ſole, and bringing forward the plane of the ſole as much as poſſible, ſo as to leave no conſiderable hollow between it and the ſock.

This being done, the tempering of the plough for its hold muſt always be produced by means of the ſhifting parts of the bridle, which the ploughman can vary in an inſtant, agreeably to the nature of the ſoil in which he is working. A well-conditioned plough will always allow this, and if a plough cannot be tempered in this way, it muſt be tempered

pered by the ſock. But, as was ſaid before, ſuch a plough is not perfect, but has an exceſs of hold in one part, balanced by a want of it in another. It may be known when a plough is perfect in theſe reſpects. Let the point of draught be fixed as high as the bridle will admit, and let the plough be worked in even light ſoil, free of ſtones, and take a good furrow. The heel of the plough ſhould not preſs on the ground at all, but ſhould even riſe a little. Then let the point of draught be fixed as low as poſſible. The heel of the plough ſhould then preſs hard on the ground, and the plough ſhould even ſhow ſome tendency to come out of the ground. If theſe things do not happen, we may be certain that the poſition of the beam is not properly adjuſted to the make of the plough, and

the poſition of the ſock, and we can now temper the plough by the ſock, ſo as to bring it into the condition deſcribed above.

It may be obſerved in general, that the point of draught muſt be fixed a little below the ſtraight line drawn from the lower end of the backband to the lower end of the ſheath behind, becauſe, in moſt ploughs, the centre of action is not far from this part of the ſheath. The diſtance of the points H and K, ſhould never exceed four inches. But this matter, together with another method of tempering the plough for the hold, by yoking the cattle more or leſs forward, will be conſidered afterwards, when we come to ſpeak more particularly of the framing and putting the plough

plough together, and of the manner of yoking.

It may, however, be added here, that the length of the beam has a great effect in making the plough go more steady, even when, in every thing, it is adjusted as above described. Directions will also be given afterwards for adjusting all ploughs to the same hold, whatever is the length of the beam.

Besides the adapting the sock in the manner now described, for giving the plough a proper hold of the ground, we must also consider its position, which is most proper for keeping the plough in the straight direction forward. It appears to me, that the most proper method for obtaining this end, is to make the land side of the sock even with the

reſt of the land ſide of the plough, and to make the whole of its taper on the furrow ſide. It is, however, a very uſual practice to ſet the point of the ſock a little to the right. The reaſon given for this is, that the reſiſtance may be diminiſhed by ſharing it between the two ſides. But this reaſon is inſufficient, when the ſock is of the proper form, and this poſition of the land ſide of the ſock produces very bad effects. It is very true, that if a ſock of the form in figure 10. were drawn in the direction of A H, inſtead of being drawn in the direction of I L, and if it had a part on both ſides of the point I, equally formed for cutting, the reſiſtance to its motion would be diminiſhed. But, in the firſt place, this reſiſtance is but a ſmall

part

part of the whole resistance of the plough. In the next place, this form of the sock at the point, will not agree with the good property, which a sock should have, of making a fair surface with the mould-board, and thus beginning the operation of the plough, in turning over the soil, as well, as cutting and raising it. Now, if the sock is made of the proper form for those purposes, that is to say, thick or perpendicular on the land side, and without a cutting edge, the resistance will be increased, instead of being diminished, by thus turning the point of it to the furrow side, because, then the land side of the sock would meet the firm ground with a perpendicular surface, unfit for cutting, and would be pushed by it to the right hand, cau-
sing

ſing the plough to loſe land, as the ploughmen expreſs it.

The bad conſequences of this poſition of the ſock, even if the land ſide were made fit for cutting, are many and great. When the ſock ſtrikes on a ſtone with its land ſide, it muſt be turned off to the furrow ſide, becauſe it cannot force the ſtone further into the firm unploughed ground, whereas a ſtone which is ſtruck by the furrow ſide of the ſock, is very eaſily forced into the open furrow. This poſition therefore of the ſock, even when cutting on both ſides, cauſes the plough to loſe land, and this bad effect muſt be balanced by giving the plough a greater tendency to the land by the form of its other parts, which muſt increaſe the reſiſtance

to its motion, or it muſt be balanced, by fixing the point of draught more to the right, which occaſions a ſtrain on the beam, acroſs it, where it is weakeſt, by the coulter-hole and mortiſe for the ſheath. All theſe reaſons, taken together, give a plain preference to the poſition of the land ſide of the ſock which I have here recommended.

We come next to conſider the breadth of the ſole, reckoned from outſide to outſide at the heel. With reſpect to which there is great difference of opinion. But an attentive conſideration of the operation of ploughing will fix our ſentiments on this matter. The ſlice which the plough cuts off from the firm ground muſt be turned over to a certain degree, or muſt, at leaſt, be ſet on its edge. This

can

can never be done unless we remove the slice its whole breadth to the right hand, as may be seen by inspecting figure 9. where A C D B represents the firm ground from which the slice is to be cut. Suppose the breadth of this to be nine inches from A to H, the coulter must come perpendicularly down thro' H I, and the slice A H I B must be turned over upon the corner B, so that the bottom B I of the slice may at least stand upright, fronting the unploughed ground, and the furrow slice stand on its side A B. Now, it is plain, that when this is done, the whole slice is shifted nine inches to the right hand. It is evident, that this can be done by no other means, than by giving the sole of the plough this breadth behind,

when

when it leaves the earth; for there is nothing elſe to preſs the earth to the right. When the ſole has this breadth, it will ſhift the earth completely, and the turning over the ſlice into the deſired poſition may then be performed by a proper ſhape of the mouldboard. If the ſoil is of looſe mould, which will not remove by turning over, or will not turn over like cloſe earth, it will ſtill be removed completely from its former bed by a ſole, which is as broad as the furrow taken by the plough.

I now add, that no greater breadth of the ſole is neceſſary. I know that a contrary opinion prevails, and that it is ſuppoſed, that when the ſole is much broader than the furrow taken by the plough, and by this means removed

farther to the right hand, there is the more room made for the next furrow ſlice to ſtand on. But that this is a miſtake, will eaſily appear, by comparing two ploughs, one of which has a ſole of nine inches, and the other of 18 inches, both employed in cutting off a ſlice of nine inches broad, and nine inches deep. The narrow plough removes the firſt ſlice nine inches to the right hand, and ſets it, as we ſhall ſuppoſe, on its edge. When it cuts off a ſecond ſlice, it alſo removes it nine inches, and ſets it on its edge. Therefore the ſecond ſlice is ſet cloſe to the firſt, becauſe its thickneſs acroſs, as it now ſtands, is alſo nine inches. The broad plough removes the firſt ſlice 18 inches to the right hand, and ſets it on its edge. It

removes

removes the ſecond ſlice 18 inches to the right hand, and ſets it on its edge. Therefore, in this caſe alſo, the ſecond ſlice is ſet cloſe to the firſt, and it has no more room to ſtand on than the firſt.

It is not the breadth of the ſole, or the removal of the earth to the right, which gives room for the furrow ſlice to ſtand on. This depends on the proportion between the breadth of the ſlice and its depth. When the ſlice is as deep as it is broad, it is preſſed cloſe to the former ſlice, whatever is the breadth of the ſole of the plough, becauſe there is no more ſpace than its thickneſs will fill up. If the ſlice is ſtill deeper, it is ſqueezed ſtill cloſer to the former ſlice, and ſo bruiſed, that part of it is forced up to a greater height

than

than it would riſe to if it had room. When the ſlice is broader than it is deep, which is the common caſe, then it has more room, when raiſed on its edge, than it can fill up, and by this means it does not preſs ſo much on the hindermoſt end of the mouldboard, but falls more freely away. But when the ſlice is much broader than deep, it falls much over, and is made to lye on its back, which is reckoned a defect in the work. This has been frequently charged as a great fault of the plough with a feathered ſock, and curved mouldboard; and it is true, that this has been oftner ſeen in working with this plough than with the plough having a ſpear ſock and plane mouldboard. But this is not a defect of the plough, but a fault

of

of the ploughman. The feather fock can raife a greater breadth of furrow than the fpear fock, and this gives an opportunity, and temptation to the ploughman to make the furrow very broad, in proportion to its depth, and this will neceffarily lay the flice on its back. But the feather fock plough, with the twifted mouldboard may, and fhould be fo conftructed, as to turn the furrow no farther over than will allow it to ftand on edge, by giving the mouldboard the proper twift, and by not giving the feather too great breadth.

As the different foils, and the different number of cattle in the yoke, muft require different breadths of furrow, no rule can be given for the

breadth

breadth of the ſole, which will fit all caſes. The furrow ſhould always be adapted to the ſtrength of the draught. For a draught of two or three horſes, the breadth of the ſole ought not to be leſs than eight inches, nor greater than ten, reckoned from outſide to outſide behind, ſquare over from the land ſide. The only advantage attending a greater breadth of the ſole, is the giving more room for the horſe and ploughman to walk on in the bottom of the furrow. But it is very improper to increaſe this beyond what is abſolutely neceſſary, becauſe the removing the earth ſo much farther to the right hand requires nearly as much more power, or labour of the cattle.

It

It muſt be obſerved, that what has been now ſaid concerning the breadth of the ſole, relates only to the feather ſock plough. The ſpear ſock plough differs in its manner of raiſing the furrow, and requires a different form and poſition, both of the ſole and mouldboard, as will be ſhown afterwards.

The form of the mouldboard ſole, and its inclination to the land ſide ſole, come next to be conſidered.

This has been very frequently formed circular, or convex, outward, like the upper part of the mouldboard. But this ſhape does not agree with the beſt manner of turning over the furrow ſlice, which ſhould be done by equal degrees, as the plough advances thro' equal ſpaces. As the plough advances

equally, the earth ſhould be moved equally to the right hand, as well as be equally twiſted over. This maxim, therefore, directs us to make the mouldboard ſole a ſtraight line from the point of the ſock, to its hindermoſt end, as is repreſented in fig. 10. where I L is the ſtraight line of the land ſide, and I K is the ſtraight line of the furrow ſide, interſecting each other at the point of the ſock.

The breadth of the feather is the next point of importance to be conſidered. This muſt be in a certain proportion to the breadth of the ſole, and of the furrow ſlice taken off by the plough. It alſo depends on the nature of the ſoil. A ſoil free from ſtones, and full of tough roots, requires a broad feather; and a ſtoney

ſtoney ſoil, with few roots, requires a narrower one. We can only mention the breadth proper for a middle kind of ſoil; and ſoils of very different qualities muſt have the feather changed on purpoſe for them.

When the ſole of the plough is nine inches broad, which will ſuit extremely well a furrow of eight inches, more or leſs, the breadth of the feather ſhould be about ſix inches. It is very uſual to make the feather of ſuch a plough eight inches broad; and this has been thought by ſome to be an improvement in the plough, becauſe it makes it to cut off all the earth from the bottom of the furrow. But this great breadth of the feather is attended with two bad effects. The ſlice being completely cut

off from its bottom, ſometimes breaks from the firm ground, before it begins to riſe on the ſock and mouldboard. By this means, it frequently happens that it is not turned over by it, but is merely ſhifted away to the right hand, retaining its former poſition, with the ſame ſurface uppermoſt which was uppermoſt before. But when the feather is two or three inches narrower than the furrow ſlice, a part of the ſlice on the corner next the furrow is not cut. This keeps that corner of the ſlice faſt till the reſt of it riſes on the ſock and mouldboard; and, by the time that it is almoſt on edge, this corner breaks of itſelf, or is very eaſily broken off by the wider part of the mouldboard ſole, and then the ſlice does not ſlide to the right,

but

but is properly turned over. The tearing of this little part occaſions no reſiſtance that is worth minding. The reſiſtance is perhaps even leſs than what would happen on cutting it with the feather, becauſe this great breadth of feather would make it cut the earth almoſt perpendicularly, which is the ſecond inconvenience ariſing from too great breadth of the feather.

On the other hand, I do not think that the feather ſhould be much narrower than ſix inches, becauſe, when too great a portion of the furrow ſlice is left uncut, it requires more force to tear it, and the work is not ſo neatly performed, and the mouldboard is preſſed up, which throws the plough to the left above, and ſpoils the ſhape intended to be given to the furrow.

The

The length of the feather ſhould be in proportion to its breadth. Ten inches along the land ſide of the ſock, or 12 inches along the edge of the feather, appears to me to be a very proper length for a breadth of ſix inches. The making it much longer will leave too little room for bending the ſock plate for fixing into the plough. It is plain, however, that the longer we make the feather it will cut more obliquely, and meet with leſs reſiſtance.

The height of the ſock feather, or its poſition with reſpect to the land ſide, is of ſome importance. The outer corner of the feather ſhould be ſquare with the land ſide of the plough, and on a level with it. It is true, that by this poſition the cut made by the feather

will

will not be exactly level with the ſole of the plough, becauſe the point of the feather is a little lower. But it is found, that when the whole feather is as much lower than the ſole as the point is, the plough is very apt to run out of the ground to the left ſide. The reaſon of which ſeems to be this: The right corner of the feather, and the right ſide of the ſock, are moſt ſtrongly preſſed down by the furrow, which is a raiſing. This twiſts the plough to the right above. If, now, the feather ſhould meet with any conſiderable reſiſtance, when the point of the ſock is higher than the right corner of the feather, the plough is apt to run upon the edge of the feather, and be thrown out of the ground to the left. On the other hand,

hand, if the right corner of the feather is higher than the ſole, it leaves a part of the furrow uncut, which the ſole muſt paſs over, and the plough is turned over to the left above, unleſs the mouldboard ſole be made higher than the land ſide ſole; in which caſe the work is not performed as it ought to be, with a ſquare bottomed furrow.

I muſt here obſerve, that as the point of the ſock cuts five eighths of an inch below the ſole, for the reaſons given above, it is neceſſary to raiſe the mouldboard ſole as much higher than the land ſide ſole, that it may be cleared by the feather cutting before it. But if it be any higher than this, it will not remove all the earth which is cut by the feather.

*Of*

## *Of the Mouldboard.*

This forms the furrow fide of the plough, by which the furrow flice is removed from that place and pofition which it has when cut by the coulter and fock, to the place and pofition which it has when finally left on the ploughed land. This part of the plough has been long neglected, the whole inftrument having been confidered as unworthy of the attention of perfons fkilled in machinery, who were apt to imagine that no rule was neceffary for the conftruction of fo fimple an inftrument. Thus it has been left in the hands of unfkilful country artifts, who, having no juft principles to guide them, could neither

neither judge of its defects, nor of the means of its improvement. But it may be affirmed, that the conſtruction of the plough, eſpecially of its mouldboard, is of a very nice and complex nature, and requires conſiderable ſkill to make it in ſuch a manner as to perform its work to the wiſh of the ploughman, and with as little labour as poſſible to the cattle. I may alſo affirm, that with reſpect to the propriety of the work, ploughs of the moſt approved conſtruction, and which have a great character, fall ſhort of what a plough may be made to perform, in a proportion not leſs than that of three to four. And, with reſpect to the reſiſtance, I may alſo venture to affirm, that with the ſame ſize of furrow, and the ſame finiſh of the work, theſe

theſe ploughs will give as much labour to three horſes as a better adapted plough will give to two.

The form of the mouldboard muſt have three properties. It muſt keep the plough to a proper hold of the ground; it muſt remove the earth to the furrow ſide, and it muſt turn it over.

1*ſt*, It is by the back of the ſock, and the fore part of the mouldboard, having the furrow ſlice lying upon them, that the fore part of the plough is kept in the ground. Therefore, the weight of the furrow will have the more power to keep the plough in the ground, in proportion as the back of the ſock, and fore part of the mouldboard, are more below it. The plough will alſo keep the ground ſo much the better, in pro-

portion as the earth ceaſes more gradually to preſs down the mouldboard, as it is turned over.

In the next place, as it is by the back of the ſock, and by the mouldboard, that the earth is removed from its firſt poſition, it is plain, that the nigher that the back of the ſock can come to a plane parallel to the ſurface of the ground, and the greater breadth of furrow that can be lying on the back of the ſock at once, the better will the under ſurface of the furrow ſlice be raiſed. It is plain too, that in proportion as we make the twiſt of the ſock and mouldboard more gradual, from the point and edge backwards, the furrow will be raiſed with leſs riſk of crumbling, and with leſs labour to the cattle.

cattle. The more direct that the surface of the back of the sock and mouldboard is for leading the earth from the one position to the other, it must be so much the better for taking the quantity of furrow which is cut by the coulter and sock all together, whereby there is a greater quantity of earth brought up from below, and made part of the new surface; But when the sock and mouldboard are of such a make as to have little breadth below the furrow, and that little of an abrupt, or irregular form, there is but little of the lower part of the furrow made to become part of the surface of the ploughed land. In land where the soil is neither clay, nor free in rising, but loose, or bound with deep roots, the plough of such a make

make cannot raiſe above half of the furrow which is cut off by the coulter and ſock; but, inſtead of this, puſhes a quantity of earth to the right, leaving the former ſurface ſtill uppermoſt, and covering that part of the furrow which ſhould have been raiſed. There is a plough made with an iron head, and ſpear ſock, without a feather; and made with ſuch a degree of land, or tendency to the left, as to require the being held over to the land ſide above, in order not to run into it. In this poſition of the plough, the ſole of the mouldboard behind is nearly as high as the ſurface of the ground; the back of the ſock being very narrow, raiſes ſo very little breadth of furrow, that the mouldboard could not follow it, if it were not ſo

high,

high. Such a plough can only make a triangular rut, and raiſes no more earth than what lyes in the angle between the coulter and mouldboard ſole, in the poſition in which the plough is going, and this earth is turned over upon the firm ground left to the right hand untouched, and covers it, ſo that the whole appears to be turned up.

In the next place, the earth is to be removed to the right hand. If this were all that is to be done, the moſt proper form of the plough would be a half wedge, with its fore edge perpendicular, moving in the cut made by the coulter, and having its land ſide applied cloſs to the firm ground. Such a plough would remove all the earth to the right hand, keeping the ſame ſurface uppermoſt which was uppermoſt before.

The

The power requiſite to draw this plough forward diminiſhes as the thickneſs of the wedge is leſs in proportion to its length, or as the plough is longer in proportion to its width. It is true, that Mr Baron, in his treatiſe on the plough, denies this, and ſays, on the contrary, that a ſhort wedge is more eaſily drawn than a long one. He alſo ſays, that when he made experiments with different wedges drawn through ſand, he found the reſiſtances to be proportioned to the length of the wedges, and he aſcribes this to the greater time which the ground has for preſſing on the longer wedge. It is very true, that when the wedge is longer than another of the ſame thickneſs, it is at any one time employed in

re-

removing more earth, in proportion to its length. If, therefore, a plough were working in mere ſand, or in ſoil as looſe as ſand, and had nothing to do but to ſhift this to the right, little advantage would be gained by making it longer: But, in ſoils which have any conſiderable coheſion, the furrow ſlice muſt be cut and bent aſide. In the performance of which, there is an advantage attending a very long and thin wedge, as well as in all caſes of cutting and cleaving inſtruments. It is very difficult to ſay what is the proportion in which the advantage will increaſe; but I may venture to aſſert, that it will at leaſt extend to that length of wedge which is neceſſary for giving ſteadineſs to the plough's motion.

It

It has been ſuppoſed, that by making the wedge round on the furrow ſide, it would require leſs power to draw it forward; and this ſuppoſition has been juſtified by obſerving the advantage which a ſhip has by being of this form. But there is very little reſemblance between the reſiſtance of the water to a ſhip, and the reſiſtance of the earth to a plough. A ſhip moves more eaſily, by being rounded in behind, becauſe, by this means, the water falls in more eaſily to fill up the ſpace left by the ſhip. This, with other reaſons, renders that form the moſt proper for a ſhip.

But, in ploughing, the earth is not to fall in behind the plough, and, if it did, it could not help the plough's motion. It is true, by rounding the wedge back-

wards,

wards, the reſiſtance of its hindermoſt part is diminiſhed; but its uſe in removing the earth is diminiſhed in the very ſame proportion; for the wedge will not remove the earth but in proportion as it widens behind. If, therefore, the wideneſs of the wedge behind is ſpecified, it will remove the earth to the ſame diſtance, whatever is the round of its furrow ſide; and the only effect of rounding this ſide, is to make it remove the earth more ſuddenly with its fore parts. This ſhape, therefore, ſo far from diminiſhing the reſiſtance to the plough's motion, ſeems rather to increaſe it, becauſe it makes the fore part of the plough act like a wedge of a more ſudden taper. Each part of the plough would act like a wedge, tapered in the

ſame direction in which a plane board would lye when it touches the plough in that part. Beſides the increaſe of reſiſtance, the wedge of this rounded form would be more apt to break the furrow, without removing it regularly, than if it were ſtraight in the ſide. It is plain that theſe inconveniences muſt be ſo much the greater as the round of the ſock is more forward.

On the whole, therefore, a ſtraight ſurface is the moſt proper ſhape for the furrow ſide of a wedge, whoſe only office is to remove the earth to the right hand.

But, as the earth muſt be raiſed up, as well as ſhifted to the right hand, the form of the wedge muſt be different from that now deſcribed, and muſt re-

ſemble

ſemble fig. 7. No. 2. Suppoſe a triangular block of wood, G F D E, of which the hindermoſt and back edge G F is perpendicular, and whoſe lower back edge F E lies in the angle formed by the land ſide of the plough and the ſole, and whoſe baſe F D E is a triangle, ſquare at F, and ſharp at E, and whoſe breadth F D is the breadth of the ſole behind. Suppoſe now, that this block were cut through level at the height A B, the lower part of it will form a ſort of wedge A C B E D F. When this wedge is drawn forwards, in the direction F E, with its back ſurface A F E B preſſed cloſe to the firm land, the fore ſurface B E D C, will ſhift the earth to the right, and at the ſame time raiſe it. Accordingly this is very nearly the form

of

of the mouldboard of the Scotch plough.

But there remains another office for the mouldboard to perform, namely, to turn over the furrow ſlice. This will not be performed by either of the wedges above deſcribed. It may be here ſaid, that the Scotch plough does really turn over the furrow. It does ſo, but for the following improper reaſon. The plough is kept over to the land above, and the wreſt, or mouldboard ſole, riſes conſiderably above the land ſide ſole. By this means the plough leaves a ſmall ridge of untouched earth between the bottom of the furrow in which it is going, and the bottom of the next. When the ſtraight mouldboard has ſhifted the earth to the top of this ridge, it cannot remain there,

but

but falls over on the next furrow. The plough, by this, appears to make good work, but this is only an appearance, becauſe there remains under every furrow a ridge of earth which is not turned up.

Since then it appears that the three fold motion which muſt be given to the earth, namely riſing, ſhifting to the right hand, and twiſting over, cannot be performed by means of a ſtraight ſided mouldboard, whatever poſition we give it, we muſt have recourſe to a twiſted mouldboard, or one of a curved form. Accordingly mouldboards have long been made with a curve or twiſt. Theſe have differed very much in their ſhape, as they came from the hands of different artiſts. Such perſons, being guided

guided by no principle, could not be expected to follow any one rule. But the operation of the plough is a certain thing. The earth is found by it in one place, and in one position, and must be left by it in another place, and in another position. If the farmers are once agreed as to the place and position in which the earth must be left, there is surely but one way in which this can be best done, and therefore, when all ploughs are made so as to do this, their mouldboards will be of one form.

With respect to the first, it seems to be the opinion of the most sensible farmers, that the earth should be shifted about nine inches to the furrow side, and that the furrow slice should stand

with

with that ſide which was formerly undermoſt now fronting the land ſide, and leaning back to the furrow ſide about forty degrees; ſo that the furrow ſlice muſt be twiſted from its former poſition about 130 degrees. This plainly fixes the poſition of the hindermoſt part of the mouldboard, where it quits the furrow. If any other poſition of the earth is found by experience to be preferable to this, it is eaſy to vary the mouldboard accordingly. My buſineſs is not to inſtruct the farmers what ſhould be the poſition of the earth when left by the plough, but to make a plough which will leave it in the poſition which their beſt judgements approve. The directions which I ſhall now give on this head, will ſhow that

my

my principles will apply equally well to any opinion which they may have in this important matter.

The principle which ſhould direct us is the following very ſimple one. As the beſt way of ſhifting the earth to one ſide, or of raiſing it, is to ſhift it, or raiſe it, by equal degrees for every inch that the plough advances, ſo the beſt way of turning it over, is to give it equal degrees of twiſt for every inch that the plough advances. If it is more ſuddenly twiſted in any one part than another, more force is required at that part, and the furrow ſlice is more expoſed to the chance of breaking in that part, by which the regular poſition in which we wiſh to leave it is deſtroyed.

This

This being the principle, I proceed to give directions, by which any workman, of common underſtanding, may infallibly make a mouldboard which ſhall perform its work as deſired, without ever having ſeen one before, or being obliged to copy. The directions will alſo help him to make a mouldboard which ſhall differ from the one to be here deſcribed in any manner he pleaſes, ſo as to perform the work with certainty, in any manner which a farmer ſhall deſire.

It follows, from the principle now laid down, that the moment the furrow is cut by the ſock, and begins to riſe on its back, it ſhould alſo begin to ſhift and twiſt to the right hand. From this it follows, that the back of the ſock

and mouldboard ſhould make one continued fair ſurface, without any interruption, or ſudden change. The twiſt, therefore, muſt begin from nothing, at the point of the ſock, and the ſock and mouldboard muſt be formed by the very ſame rule.

In the next place, there muſt be ſome certain line of the furrow, on which we muſt always reckon the twiſt. This muſt certainly be reckoned on a line drawn ſtraight acroſs the furrow, ſquare with the land ſide. Let us ſuppoſe, that the plough has juſt entered on a ridge, which has been cut ſquare acroſs, and has advanced till the heel has juſt entered the ridge. Then R I D in fig. 13. will repreſent the ſod as it then lies on the ſock and part of the mould-

mouldboard. R I is the ſide of the ſod which was cut by the coulter, and R D will repreſent the end of the ſod as it was cut acroſs, while lying in the ridge. Therefore the angle R is exactly ſquare, and the angle D is within the ſquare about 16 degrees, when the length from the point of the ſock to the heel is 33 inches, and the breadth of the ſole is nine inches, which is nearly the uſual dimenſions. This angle D continues the ſame from the time that the point of the ſock begins to raiſe and turn the ſod, till the heel paſſes the end of it at DR. As the plough advances, the angle approaches nearer to the ſquare; but, we may, without any material error, ſuppoſe, that it never changes from the time that the plough begins to raiſe the ſod till it quits it. This ſuppoſi-

tion

tion is very near the truth, and will give us very eaſy methods of forming the mouldboard. I ſhall point out two methods for this purpoſe.

The firſt is by means of a protractor and ſcale.

The protractor is a ſemicircle, divided as uſual into 180 degrees. It is repreſented in figure 11. and has an index or pointer B O A moveable round the centre O. One of the radiuſes O C is made to project to a convenient diſtance beyond the circumference. The uſe of this inſtrument is ſimilar to that of the common ſuit-ſtock, uſed by carpenters and joiners. If the pointer A be ſet to any number of degrees, ſuppoſe 50, then the angle made by the edges C O, B O, will alſo be 50 degrees,

and

and a piece of wood may be worked to this bevel, by applying it ſquare over to the edge of the piece of wood. The piece of wood may alſo be worked to any twiſt. Suppoſe, that it is required to be twiſted, in ſuch a manner, that it may be ſquare at one end, and half ſquare at the other. Let one ſide of the piece of wood be planed flat, and with a ſtraight edge. Let it be divided along this edge into 45 equal parts, make the mark 90 at that end, where the wood is to be ſquare. Mark the firſt diviſion 89, the ſecond 88, the third 87, and ſo on, till you come to the end, which will be marked 45. Now, ſet the index of the protractor at 90, and apply the angle C O B to the piece of wood at the mark 90, ſquare with its edge,

edge. Let the wood be worked off at that place till it juſt fits the angle of the protractor. In like manner, ſet the index at 89, and apply the angle C O B to the mark 89 upon the piece of wood, ſquare over its edge, and let the wood be worked away till it fits the angle in that place alſo. Proceed in this manner with all the different degrees of the protractor between 90 and 45, and the correſponding points on the edge of the piece of wood. It is evident, that by this means the piece of wood will be formed, ſo that the wrought ſurface ſhall have a twiſt, from the ſquare to the half-ſquare, increaſing gradually from one end to the other, and every part of its length has a gradual increaſe of twiſt. We may alſo vary this twiſt in

any

any manner we pleaſe, making it more ſudden in one part than another. This will be done by making the ſpaces along the edge unequal, namely, ſmaller where the twiſt it intended to be more ſudden, and wider where it is intended to be more gentle.

The other inſtrument is the ſcale, repreſented in figure 12. which is nothing elſe than a piece of hard wood, planed flat, and ſtraight, and divided into any number of parts, equal or unequal, according to the nature of the twiſt which the piece of wood is to have. The only uſe of this ſcale is to ſave the trouble of dividing the edge of the piece of wood to be twiſted. It is of uſe, therefore, only in theſe caſes where we have occaſion to make ſeveral

ral pieces of wood of the ſame dimenſions, and of the ſame twiſt.

To uſe this ſcale, the edge of the piece of wood muſt be worked flat and ſtraight, and in ſuch a poſition that there may be wood enough every where to complete the twiſt. The ſcale muſt now be fixed to the piece of wood with pins or ſcrews, in ſuch a manner that its different diviſions may correſpond to thoſe parts of the edge where the twiſt is to be, of that number of degrees which is expreſſed by the diviſions.

In order to apply theſe inſtruments to the purpoſe of forming the mouldboard, another circumſtance muſt be attended to. It was obſerved before, that when the plough has advanced the whole length of its ſole, a line drawn ſquare

ſquare acroſs the furrow ſlice, as it then lyes upon the mouldboard, does not make a ſquare angle with the mouldboard ſole, but falls about 16 degrees within the ſquare, making an angle of about 74 degrees. For this reaſon, it is neceſſary, that when the edge B O of the protractor's index is applied ſquare to the edge of the mouldboard ſole, the plane ſurface of the protractor ſhall not be ſquare with that edge, but make an angle R D I of 74 degrees. (ſee fig. 13.) For this purpoſe, the tail of the index BO muſt not be a ſquare piece, but bevelled to 74 degrees, as is repreſented in figure 11. No. 2. where B E F G is the index ſeen endways, having its two angles G and E of 74 degrees. The protractor A C goes ſlanting through it,

and turns round the pin H O, which is ſquare with the ſides B G and E F. By this means the protractor A C will make an angle of 74 degrees with the upper edge of the index B E.

The protractor, with this change being applied as above directed, with its index ſquare with the outer edge of the mouldboard ſole, will always give the proper twiſt for the furrow, reckoned directly acroſs it.

Now, let C, fig. 13. be the hindermoſt point of the mouldboard above, and let I D E be the ſtraight edge of the mouldboard ſole, or rather of the ſcale fixed to it, and let E be the point, to which the index of the protractor is applied ſquare, when the ſide C O (fig. 11.) being opened to 130 degrees, juſt touches

touches the point C of the mouldboard. (fig. 13.) Meaſure the length from E to the point of the ſock, and make this the length of the ſcale, (fig. 12.) Divide this ſcale into 130 equal parts, and number the tens as in the figure 12. Now, let this ſcale be applied to the ſtraight edge of the mouldboard ſole, and there fixed with ſcrews, ſo that the beginning of the diviſions may be at the point of the ſock, and the diviſion 130 will then project a good way behind the mouldboard. This is repreſented in fig. 14. where C I is the land ſide ſole, C is the point of the ſock, and C B is the ſcale. The protractor being applied to this ſcale, in the manner above directed, will regulate the mouldboard to one uniform twiſt, from its hinder-

hindermoſt point to the very point of the ſock, forming at once the mouldboard itſelf, the fore edge of the ſheath, and the back of the ſock.

In uſing theſe inſtruments, we muſt always be careful to apply the edge of the index ſquare with the edge of the mouldboard ſole; and the part of the ſcale which projects behind the ſole muſt be ſupported, ſo that it may not be preſſed out of the ſtraight by applying the ſcale to it. Neglect in either of theſe particulars, may produce great errors in the form of the mouldboard.

It muſt now be obſerved, that the directions here given require a correction, on account of the plating with which the mouldboard is to be covered. This may be done by altering the diviſions

of

of the ſcale in the following manner: The ſcale being four feet long, it is divided into 130 parts, which anſwers to the 130 degrees of twiſt, and it is marked at every five. This makes 26 principal diviſions, each foot having $6\frac{1}{2}$. Set off the firſt 20 diviſions from C to H, (fig. 14.) the ſame as if the whole ſcale were divided equally, and put the mark 20 at H. Set off $2\frac{5}{8}$ inches from H to A, and put the mark 20 again at A. Set off $8\frac{3}{4}$ inches from A to D, and put the mark 50 at D, and divide the ſpace A D equally. Set off $5\frac{1}{8}$ inches from D to E, and put the mark 65 at E. Let the diviſions between 50 and 65 gradually increaſe, being ſmalleſt at D, and biggeſt at E. The diſtance from E to B will now be two feet, and is to be divided

vided equally, in the ſame manner as the whole ſcale would have been without this correction. The blank between H and A is to make up for the difference between the inner and outer ſide of the ſock; and the inequalities of the other diviſions is to make up for the different thickneſs of the plating. Although the mouldboard made by this corrected ſcale has not the regular twiſting of its parts, yet the ſurface of the iron will have that regular twiſt which is intended.

From this deſcription of the inſtruments, and of the manner of uſing them, it is plain, that whatever opinion farmers may have concerning the gradual variation of the twiſt which the plough muſt give the furrow, a mould-

board

board may be made by these instruments, which shall produce the twist which is desired. Accordingly the following division of the scale gives a form of mouldboard which is much approved of. The numbers in the first column are those which are to be placed on the divisions of the scale, and the numbers in the second column are the distances from the hindermost end of the sock.

| | | | *Feet.* | *Inches.* |
|---|---|---|---|---|
| 20 | - | - | 0 | 0 |
| 30 | - | - | 0 | 3 4/5 |
| 40 | - | - | 0 | 7 2/5 |
| 50 | - | - | 0 | 9 1/5 |
| 60 | - | - | 1 | 3 1/5 |
| 70 | - | - | 1 | 6 7/8 |
| 80 | - | - | 1 | 11 |
| 90 | - | - | 2 | 3 1/2 |
| 100 | - | - | 2 | 7 7/8 |
| 110 | - | - | 3 | 0 1/5 |
| 120 | - | - | 3 | 4 2/3 |
| 130 | - | - | 3 | 9 |

The following division of the ſcale alſo produces a mouldboard which has given great ſatisfaction.

| | | | *Feet.* | *Inches.* |
|---|---|---|---|---|
| 20 | - | - | 0 | 0 |
| 30 | - | - | 0 | $3\frac{1}{2}$ |
| 40 | - | - | 0 | 7 |
| 50 | - | - | 0 | $10\frac{1}{2}$ |
| 60 | - | - | 1 | 2 |
| 70 | - | - | 1 | 6 |
| 80 | - | - | 1 | 10 |
| 90 | - | - | 2 | $2\frac{1}{2}$ |
| 100 | - | - | 2 | 7 |
| 110 | - | - | 3 | 0 |
| 120 | - | - | 3 | 6 |
| 130 | - | - | 4 | 1 |

I have already obſerved, that this method alſo forms the back of the ſock, and the fore edge of the ſheath. But

as it is convenient to know pretty nearly the inclination and curve of the ſheath, before it is framed into the beam, I ſhall here give directions, illuſtrated by fig. 15. The perpendicular height A C of the ſheath, reckoned from the ſole to the under ſide of the beam, at the fore ſide of the tenon of the ſheath, is 13¼ inches, and its inclination forward C D is 14¼ inches. The fore ſide of the ſheath may be formed to a circle I D, having the radius D O of 18 inches, the centre O being in a perpendicular above E, which is 19 inches from C. This will leave a ſmall ſpace between A C, which is not made up by the ſheath, but this is of no detriment, for if the ſheath were ſo far forward, working it to the twiſt would weaken its tenon.

The

The part of the ſcale before 20 is of no uſe in making the mouldboard, as it is before the point of the ſheath. It ſerves to ſhow the point C, fig. 14. where the land and furrow ſides interſect each other. The ſcale muſt be fixed ſo, that 20 at A is equally forward with the point of the ſheath, and the edge which is uſed for forming the mouldboard muſt be 2½ inches from the land ſide at the point of the ſheath, and 3½ at I. When the ſhoeing is put on the wood at this ſize, it makes the ſole to be above nine inches, which is abundance of breadth for general purpoſes.

The other method which I ſhall give for forming the mouldboard, is by an inſtrument repreſented in fig. 17. which we call a bevel. It conſiſts of a ſtraight

piece

piece of wood K M, which may be called its handle, and a rod N P, fixed into it at an angle equal to that which the croſs line R D of the furrow, fig. 13. makes with the mouldboard ſole, namely, an angle of about 74 degrees. The lath A B is faſtened to its upper ſide, parallel with its edge, ſo as to form a ſhoulder, which can be applied to the edge of the mouldboard ſole. This inſtrument is repreſented endways in No. 2. by which the angle or ſhoulder may be better ſeen.

In order to ſee the manner of uſing this inſtrument, conſider fig. 16. where G is the point of the ſock, G L the land ſide of the plough, C R E a line drawn parallel to it, along the furrow ſide of the ſheath, and C I the furrow ſide of the

the mouldboard ſole. R A is the upper mould of the mouldboard, drawn to its proper thickneſs and poſition. This upper mould muſt be taken from a pattern made by the protractor and ſcale: Or we may come extremely near the equal twiſt, by making R A a ſtraight line, ſet on at R, oppoſite to the point Y, which is two feet diſtant from the point of the ſock. R A muſt make an angle A R E of 46½ degrees.

Now, let a piece of wood be choſen for the mouldboard. This muſt be at leaſt eight inches thick, and of the ſhape repreſented in fig. 16. No. 2. The lower edge C H muſt be about 22½ inches, the height O P 12 inches, the inclination forward C P of its fore ſide muſt be 11 inches, and the upper edge

O A

O A muſt be about 24 inches. When this piece is joined to the plough, in ſuch a manner that the mouldboard can be worked out of it, it will ſtand in the poſition, fig. 16. A O R B being its upper edge, and H C D I its under edge. For this purpoſe, it muſt be hewed away with a perpendicular face on the land ſide, in ſuch a manner that the loweſt point forward C of figure 16. No. 2. may be at C in figure 16. No. 1. which is the interſection of the furrow ſide A I, with the furrow ſide of the ſheath C R; and the higheſt point A, behind figure 16. No. 2. muſt fall on A No. 1. The perpendicular face abovementioned muſt now apply cloſe to the furrow ſide of the ſheath, all the way from C to S. Now, let the mould

C I

C I be drawn on the under edge of the piece of wood, and the mould R A on its upper edge, in their proper poſition, or inclination to each other, as in the figure, and let the fore edge of the ſheath on the land ſide be formed according to figure 15. Every thing is now ready for applying the bevel.

Lay the ſtock or handle of the bevel along the line G C, the end M of the ſtock being towards G, and the check or angle of the ſtock being applied cloſe to G C, ſlide it back along G C, till the rod P N of the bevel comes to touch the ſheath, which it will do at firſt on the furrow ſide. Let the wood be hewed away till the rod now touches the fore edge of the ſheath on the land ſide. In this manner proceed backwards, al-

ways

ways ſliding the ſtock along the draught C I, and hewing away the wood till the rod can touch the fore edge of the ſheath on the land ſide. This will form the mouldboard as far as the top of the ſheath. Proceed in the ſame manner, always applying the ſtock to the draught C I, and hewing away the wood till the rod can touch the mould draught R A, drawn on the upper edge of the mouldboard in its different parts. When this is done, if the ſtock be gradually drawn along C I, and the rod applied to the fore edge of the ſheath C R, and the upper mould draught, the rod itſelf will ſlide along the ſurface of the mouldboard, and will, in every ſituation, be perfectly ſimilar to the edge of the protractor, and perform the ſame office.

The

The mouldboard made in this manner will hardly differ from that made by the ſcale and protractor, and may, like it, be varied at pleaſure, by varying the form of the fore edge of the ſheath, and the form of the upper mould draught R A.

A gentleman, who has been ſo good as to look over this performance before it was put to the preſs, has favoured me with the following obſervations on theſe two methods.

" The method with the ſcale and pro-
" tractor does not give an equable twiſt
" of the mouldboard in any part, ex-
" cept juſt at the point I. The me-
" thod with the bevel is exact all the
" way from the point of the ſock to I.
" Both the methods give too much in-

" clination to the furrow after it passes
" I, and leave it turned farther than
" 130 degrees."

As I make no pretension to mathematical knowledge, I will not dispute the truth of this observation, especially as I am informed by my friend, that the deviation from a regular twist is not so great as to affect the performance of the plough very materially. Besides, the reader sees by this time, that this method of forming the mouldboard, whether by the protractor, or by the bevel, will enable us to give it a regular twist, or any twist we please. We have only to vary the divisions of the scale for the protractor, in such a manner as a mathematician shall direct for the twist required. If we use the bevel, the mathematician

thematician can inform us what ſhape of the upper edge of the mouldboard will form the whole ſurface to the deſired twiſt. And I reckon it a matter of ſome conſequence to have pointed out a rule, by which workmen may make mouldboards with abſolute certainty, according to any given principle, whereas at preſent they are made at random, or by the eye.

The laſt circumſtance to be taken notice of with reſpect to the mouldboard, is the form of its hindermoſt end. This has been greatly varied by different workmen, although there is only one way of making it proper for its work, which is, that all the parts of it ſhall leave the furrow in one inclined plane. This may be very nearly done

in

in the mouldboard now defcribed, by making the hindermoft end of the fame curve with the fore end, the curve cutting the mouldboard, all at one length, as in fig. 13. When the mouldboard is of any other form, its hindermoft end may be formed fo as to leave the furrow in one regular inclined line, by the following eafy method. Let two parallel lines be drawn upon an even floor, at the diftance of the extreme point of the heel of the mouldboard fole, from the land fide of the plough, as is reprefented in fig. 16. by the lines G L and Q T. Let the plough be fet with its land fide along G L, fo that the heel of its mouldboard fole may be at I. Now, let a ftraight plank, of the fame breadth with the mouldboard, be fet with

with its ſtraight edge along the line Q T, but leaning over to the furrow ſide. Let it now be turned round upon the line Q T, like a door on its hinges, till it touch the hindermoſt end of the mouldboard, which muſt be cut away till the plank touches it from the heel to the top, and ſtands at the proper inclination to the furrow ſide. After this deſcription of the mouldboard, and this account of the principle which leads to the conſtruction, it ſeems unneceſſary to draw any compariſons between this mouldboard and thoſe of other forms; and I doubt not but that the reader will agree with me in thinking that this merits the preference.

As the deſcription hitherto given of the plough, has all along related to the plough

plough which has the feather ſock on the ſheath, it may be thought that this conſtruction is proper for that kind of ſock, and that manner of framing, only. But it will correſpond equally well with other ſocks and methods of framing.

When land is ſtoney, the ſpear-ſock is thought to be the moſt proper, and, in this caſe, a plough framed with a head is thought better than one framed in the manner already deſcribed. Such a framing is repreſented in fig. 18. In this framing, the land ſide of the ſheath muſt be even with the land-ſide of the head, and with the land ſide of the fore and hinder end of the beam. This is done, by giving the ſheath a ſhoulder upon the land ſide, both above and

and below, and not making its tenon on the land ſide, as is uſually practiſed. In this manner, the upper tenon of the ſheath may be through the middle of the beam, which will give it the greater ſtrength. Thus the land ſides of the head and ſheath, and ſtilt, are in one plane.

The curve of the ſheath and its inclination forward, are to be the ſame as in fig. 15. as far down as the upper ſide of the head. The plough however will not be materially hurt, although the ſheath has not ſo much curve below, which would perhaps weaken the lower tenon of the ſheath, which, in this conſtruction, is more over to the furrow ſide than uſual.

The

The ſtilt may be either of ſuch a mould as is repreſented by the dotted lines in fig. 18. ſo as to frame into the hindermoſt part of the head, or it may be of the ſhape expreſſed by the ſhaded part of the figure; with a chock of wood between it and the heel, and an iron bolt through it, as C D. This is a much ſtronger form, and leſs liable to rack. This framing of the plough may be uſed either with a ſpear ſock, or with a feather ſock. The ſpear ſock is repreſented in fig. 19. which ſhows the ſole of the head and furrow ſide, inclined as they ſhould be, when the mouldboard is made according to fig. 14. A croſs ſection of the hindermoſt part of the ſock is ſeen at N I, where E B A C is the iron work of the ſock, B A

its back, B E its land ſide, and A C its furrow ſide, and C D the ſole of the head. The back of this ſock behind will have very nearly the ſame inclination with the mouldboard of fig. 14. at that place.

The greateſt difference between this and the feather ſock plough is in the height of the mouldboard ſole. As the ſpear ſock does not cut the furrow ſo low before the mouldboard ſole as the feather ſock does, the ſole muſt be 1$\frac{1}{4}$ inch higher all its length. Different ſoils require a variety in this reſpect.

Another difference is, that the point of the ſock muſt not be ſtraight with the land ſide, becauſe, in this caſe, it would be too much to the left, and would not raiſe up all the furrow, when

the coulter is placed as before directed, which is its most proper position in this plough, as well as in the feather sock plough.

When the feather sock is put on this head, as is represented in fig. 20. the hindermost end of the sock is as N 2. C A B being its back, and C E its land side. This sock has nearly the same inclination behind with the mouldboard of fig. 14. at that place. As this sock has a feather, the mouldboard sole may be made as low as when the sock is in the sheath. The point of the sock must also be straight with the land side of the plough.

A feathered sock plough with a head, will admit the sock to be flatter above than when the sock is on the sheath, by which

which means there is more length of the plough below the furrow before it is turned up, and the plough keeps better in the ground, and ſeems, in this reſpect, preferable to the other, in ſoils where obſtacles frequently occur, which are apt to put the plough out of the ground.

. When the iron head, with the feather ſock, is employed, the twiſt of the mouldboard is formed in the ſame manner, but is extended more forward, becauſe the hindermoſt end of the ſock is ſmaller.

*Directions for making Sock Maundrels.*

It is beſt to have theſe of caſt metal. This requires a wooden pattern. This, for the feather ſock on the ſheath, muſt be formed to the regular twiſt by the ſame inſtruments which are uſed for forming the mouldboard. For the ſock on the head, the pattern is made proportionably flatter, becauſe, in this caſe, the twiſt is extended further forward.

*Directions for framing the Plough. fig.* 1.

When the ſundry parts of the plough are to be marked for the tenons and mortiſes, they muſt be laid in the poſition which they are to have when the plough

plough is made. The poſition of the beam for giving the proper hold depends on two things, *1ſt*, the different length of the beam, and the height of its fore end from the plane of the ſole. *2d*, The inclination of the line of draught. If all ploughs were of one length, from the part which turns the furrow, to the part of the beam by which the cattle draw, the rule for giving them all the ſame hold is very ſhort and ſimple; namely, to place the fore end of the beam at the ſame height above the plane of the ſole. But this rule will not apply when the beams are of different lengths. The following method may therefore be practiſed.

A B (fig. 22.) is a ſtraight batten about 10 feet long. Let there be a notch, ſtud, or other mark C, about 3 feet,

6 inches from the end A. Make the point H about 4 inches farther from A, which, in moſt good ploughs, is nearly the diſtance between the point of the ſheath, and the interſection of the line of draught with the ſole of the plough. Draw a line H L, making an angle L H A, equal to the inclination of the draught. This inclination is to be found by directions which will be given afterwards. Make H M nine feet, and draw the perpendicular M L, meeting the draught line in L. Make L G about five or ſix inches, and draw the line G H. Take a ſtraight batten E F, and lay it on the line G H, ſo that its middle K may be about four feet from H. Let the battens E F and A B be connected by a batten A K nailed to both,

which

which will keep E F in its proper place and inclination.

Now, let the ſheath be cut by a mould to its proper curve forward, and a draught made for the ſole, or let it be alſo formed on the end which is to be the ſole. Let it alſo be marked at the height, where its tenon is to begin. Let the ſtilt alſo be cut to its proper mould. Now, place the ſheath with its ſole draught on the edge of the batten A B, and its point at the noth c. Place alſo the ſtilt in its proper poſition. Then lay the beam, with the under part of its fore end, on the edge of the batten E F, and its under ſide on the tenon mark of the ſheath. Slide the point of the beam backwards or forewards along the edge E F, always keeping its under

ſide

side to the tenon mark of the sheath, till the other end of the beam projects sufficiently behind the stilt, for giving a proper length of tenon. The mortises and tenons must now be marked, while the parts are in this position, and the plough will have its proper hold for the inclination of the draught, and when the bridle is added, the plough will keep its heel well to the ground.

If the plough is to be worked with a bridle and chain, a piece must be fixed to the fore end of the beam, when it is laid down for marking, which will make the part which touches the batten E F to correspond with the situation of the point of draught in the going plough.

The part of the batten A B, which is behind the heel of the plough is for adjusting

justing the height of the ſtilt handles.

This muſt be the ſame whatever is the length of the ſtilt, and for ordinary men, muſt be about three feet two inches from P to B.

The aſcent or inclination of the line of draught depends both on the height of the cattle, and the diſtance from the plough at which they are yoked. When the horſes are ſtanding in the draught, let a plumb line be applied to that point of the chain or draught rope which goes through the backband. Meaſure the height from the ground, and the diſtance of the point of the ground where the plummit falls from the point H, three inches behind the point of the ſheath. When two horſes are going abreaſt, as one of them is on the un-

ploughed ground, we muſt add half the depth of the furrow to the meaſure taken as above directed. When one horſe is yoked before another, in ſuch a manner as to make two aſcents of draught, a middle between theſe may be taken, if both are of equal ſtrength. If they are not equal in ſtrength, the medium line of draught will be nearer to the draught line of the ſtrongeſt. Thus, if H N be the draught line of the hindermoſt horſe, and H O the draught line of the foremoſt; and if the draught of the firſt is ſtronger than that of the laſt, in the proportion of five to four, for inſtance, make H N five parts of any ſcale, and H O four parts of the ſame ſcale. Make N P parallel to H O, and O P parallel to H N. Theſe two lines will

will meet in P, and H P will be the direction of the medium line of draught.

The framing on the sheath requires only this farther direction in addition to what has been already said, namely, that in order to make its land side on the same plane with the land side of the sole, and, at the same time, its tenon near the middle of the beam, it must have a shoulder on the land side. This will seldom need to exceed $\frac{3}{8}$ of an inch. The land side of the stilt must also be in the same plane with the sheath and sole.

In fixing on the furrow side of the plough, the inside of the mouldboard must be hewed till it is reduced to the thickness of 2, or $2\frac{1}{2}$ inches in the middle, where the little stilt is to be

fixed,

fixed. The upper ſide and hindermoſt end may be made thinner, becauſe they are expoſed to leſs ſtrain. The mouldboard is then fitted on to the ſheath, at its proper inclination with the land ſide of the plough, and the proper width behind. The little ſtilt is then fitted to, and marked for its proper height. The mouldboard being now taken away again, the little ſtilt is nailed to its proper place. The mouldboard being again put on as before, the ſtilts are bored for the rungs, and marked for the length.

*Of the Uſe of a Chain on the Plough.*

When a plough is made with ſuch a degree of hold as in fig. 24. the point C of the bridle, to which the draught is applied, is kept in its poſition by means of a chain C D, which is hooked to a ſtaple at D, at ſome diſtance behind on the beam. The chain may be made ſhorter or longer by means of the click in the ſtaple D; and by this means, the point of the bridle C is kept in a circle round the centre bolt B, and the plough gets more or leſs hold, according as the chain is made longer or ſhorter. When the plough is mounted in this manner, the point of the beam is ſet higher than when no chain is uſed, although the height

height of the ſheath be the ſame, as has been already obſerved in the directions for framing. The ploughmen call this giving the plough greater redd or freedom. This form of the plough enables us to give it greater changes of hold than when a bridle is uſed without a chain, becauſe the bridle may be made longer from the bolt, without any danger of breaking, being ſupported by the chain. The part of the beam alſo between the bridle and ſtaple is ſomewhat ſecured from breaking upwards; and if the ſtaple could be conveniently placed at the very ſtilt, it would be ſtill more ſecure. This bridle is made with notches on each ſide of the middle, in order to give the plough more or leſs land.

When

When two horses go a-breast, the draught line falls in with the direction of the plough, or is right along the beam. But when the horses go all in the furrow, the draught line is then removed to the right, something more than half the breadth of the furrow, (see fig. 25.) where A D B represents the draught line, when the horses are all in the furrow, and A E C is the draught line when the horses are a-breast. D is the point where the line A D B falls in with the furrow, and A is the point where it falls in with the centre draught. D E will then be the distance of the notch of the bridle, upon which the chain should be placed, from the other draught line A E C. It may be observed of this manner of drawing, that the draught

draught line can never fall parallel with the direction of the plough. Indeed, even where the horses are a-breast, the draught line is not exactly in the direction of the plough, because the land horse generally keeps more than nine inches from the edge of the furrow.

### *Of the Use of Wheels to a Plough.*

From the description which has already been given of the various parts of a plough, and the reasons which have been offered for giving to each of them the form which I have recommended, the reader will see what part of the work is performed by each, and will be able to judge of any alteration which may be proposed by way of improvement, whether

whether or not they tend to make a plough perform better work, be more eaſily drawn, more regular in the draught, or more eaſily managed. Care has been taken of each of theſe things in the forgoing conſtructions, and experience ſhows that a plough may be ſo made, as that, when working in even and well dreſſed ground, the plough will perform the work almoſt of itſelf, requiring very little attention from the ploughman.

But ploughs have been uſed which are of a very different conſtruction, having many parts which are not in the plain plough, the ſubject of the foregoing ſheets. As theſe ploughs are now in great vogue, and much uſed both in England and other countries, and as

the parts added are intended for producing ſome of the good effects juſt now mentioned, it will be improper to paſs them over without notice in this treatiſe. The chief of theſe propoſed improvements is the addition of wheels to a plough, which ſhall therefore be particularly conſidered in this place.

It has been a very general opinion, that the addition of wheels is an improvement of the plough, but artiſts have differed exceedingly, both as to the manner of applying them, and the parts to which they ſhould be applied. Since theſe parts are only ſubſervient to the part of the plough which really performs the work, and as the manner of acting of a wheeled plough differs conſiderably from that of a plough without

wheels

wheels, we must consider particularly their action, at the different parts to which they may be applied, in order to judge of their advantages or disadvantages. The reader also will easily see, that the form of that part of the plough which is in the ground, and really performing the work, must be regulated by the same principles in both cases, and that what is most proper for the one will also be most proper for the other.

One manner in which wheels have been used, is to have two wheels applied to the beam, by a carriage. Wheels applied in this manner have their principal effect in regulating the plough, by giving it a certain quantity of furrow, either in breadth or depth. While one wheel

wheel continues in the furrow, and the plough is ſet to take any given breadth, it muſt keep that breadth very regular-ly, and not be liable to make any ſud-den bend, and is therefore very proper for keeping ground ſtraight that is al-ready laid out in ſtraight ridges. Alſo, when the beam is fixed to any height of the wheel carriage, the plough muſt be kept at a fixed depth, and, by ſhifting the beam higher or lower, the plough may be made to go deeper or ſhallower, as occaſion may require. When, there-fore, the ſoil is equally deep, and free from obſtacles of ſtones or roots, this plough muſt require little labour in managing it.

But,

But, on the other hand, when the surface is not a plane, either level or inclined, but has a number of heights and hollows, as is frequently the case, especially in cross ploughing, the wheeled plough cannot be so proper as the one without wheels, which the ploughman can regulate to his mind, whereas the wheeled plough is out of his power. In like manner, when the soil is not equally deep in the length of a furrow, or would require to be ploughed to different depths at different places, it cannot be proper to have the plough fixed to one certain depth. It is known that, in general, the crown of the ridge will admit of being deeper ploughed than what is near the furrow.

It

It muſt alſo be obſerved, that in making the firſt furrow of the ridge, the wheel which, at all other times, goes in the furrow, muſt now be as high before the furrow is made, as the one on the unploughed ground. This requires the plough to be altered every time we make the firſt furrow of a ridge. On the other hand, when a plough is making the laſt furrow of a ridge, the wheel, which, at all other times, goes on the unploughed land, is now in the furrow of the former ploughed ridge, or on the oppoſite ſide of the ſame ridge. This will, in like manner, require an alteration of the plough.

From theſe obſervations, it appears that inconveniencies ariſe from keeping the plough in one uniform depth, and

that

that by the frequent alterations here specified, very little labour is saved to the ploughman upon the whole. It must also be observed, that the part of the wheeled plough in the furrow must be the same as that of the plain plough, when the centre draught is the same. But, in this plough, the draught line has often two different ascents, one from the part of the plough acting in the furrow, to the wheel carriage, and the other from the carriage to the cattle. To this is added the draught of the wheels and carriage.

In finding the draught line of this plough, we must consider the parts upon which the pressures are exerted. With respect to the part of the plough which is in the furrow, the pressure is exerted on

on that point which we have called the centre of action. This will vary a little, by a change in the depth of the furrow, and by any difference in the length and position of the sock and coulter. But, in general, when the distance between the point of the sock and the heel is two feet nine inches, the draught line will intersect the sole about 14 inches back from the point of the sock.

With respect to the carriage, the pressure of the draught is always exerted on that point to which the draught is applied. Some may think, that the pressure of the work is exerted on that point where the beam rests upon the carriage. But, in whatever way the carriage draws the plough, or beam, or

in

in whatever way the carriage is made, it has all one effect, and the draught line will never follow any elevation of the beam, nor the various turnings of the different parts which connect the centre of action with the part of the carriage to which the draught of the horses is immediately applied, but makes a straight line through them all. Thus, then, there are two ascents of draught, one from the centre of action to the draught point of the carriage, and the other from thence to the horses. If these two ascents make but one straight line, the plough will, in this respect, differ very little from the plough without wheels, because then there is no pressure upon the wheels. It is true, that the plough will not go

deeper, but it will be eafily thrown out. If the firft afcent of draught is greater than the fecond, fo as that they make an angle below, at the part of the carriage which is drawn by, there will then be a preffure upon the wheels, and the plough will be regulated in its depth, and will go fteady. This preffure upon the wheels will be fo much the greater, as the two afcents of draught differ more from each other.

It is thought that power is gained by thus raifing the line of draught upon the carriage, becaufe, in the common way, the draught is partly employed in pulling the plough out of the ground, and the remainder only is employed in pulling the plough forwards. In the wheeled plough, the draught of the cattle

cattle may be made parallel with the bottom of the furrow; but it muſt be here obſerved, that by giving this direction to the draught of the horſes, we increaſe the preſſure of the wheels; and while power is gained by leſſening the aſcent of draught, power is alſo loſt by increaſing the preſſure upon the wheels. I am of opinion, that, when theſe circumſtances are duly attended to, and when we conſider the uneven and compreſſible ſurface upon which the wheels muſt move, we ſhall find that no power will be gained by placing the draught higher upon the carriage than the ſtraight line which joins the centre of action of the plough with the height of draught, as it comes from the lower end of the horſes backband. With reſpect, there-

therefore, to the eaſineſs of draught, the wheeled plough does not ſeem to poſſeſs any advantages, and it is loaded with the additional weight of the carriage and wheels.

There is a wheeled plough of a much more artificial conſtruction than the one now deſcribed, having wheels or rollers applied to that part of it which is in the furrow.

In order that the furrow ſide of a plough may ſhift and turn the earth in the manner deſired, the plough muſt be ſupported againſt the reſiſtance which it meets with from the earth. As the earth is raiſed and preſſed to the right, the plough is preſſed downwards, and to the left, and muſt be ſupported by the bottom of the furrow, and by the

firm

firm ground to the left. The sole and land side of the plough are therefore strongly pressed, and exposed to great friction, in the same manner as the sole of a sledge drawn along a soft road. In the plough now under consideration, a wheel has been substituted in place of the sole, and another wheel, or rather roller, with a perpendicular axle and horizontal motion, has been substituted in place of the land side. This plough differing from a common plough in the same manner as a wheeled carriage differs from a sledge, it has been called a carriage plough, while the common ploughs are called sledge ploughs. It is also commonly known by the name of Moore's patent plough. As these wheels are placed in the most proper manner

manner for producing the effect that is desired, this plough is very fit for enabling us to judge of the value of this improvement. The improvement is supposed to be the same upon the plough that wheels are supposed to be upon a sledge. The superiority of the wheel-carriage above the sledge is well known. Now it is thought, that as the wheel, which, in this plough, performs the office of the sole, is 16 inches in diameter, while its gudgeon is but one inch, the resistance to the plough's motion arising from the friction of the sole is diminished 16 times.

Granting this, the improvement is not so great as is commonly imagined. For a wheel of 16 inches diameter cannot be placed so near the point of the sock, as

to

to perform the office of the sole. It only performs the office of the heel of a plough. Now, we have seen, that the pressure upon the heel of a plough, and consequently its friction, is not considerable, if the plough is constructed according to good principles, being nothing more than what is necessary for making the plough steady in its motion. In Moore's patent plough, the pressure of the heel may be reduced to nothing, because it has wheels under the beam. But in the way in which it is commonly made, the pressure at the heel is very considerable, and the friction may be greatly diminished by means of the wheel at the heel of the plough. This advantage however is much more than balanced by other inconveniencies. The

ſole of a common plough being made ſmooth and even, and in the direction of the plough's motion, it ſuffers no reſiſtance, but what ariſes from friction alone. Preſſing upon the furrow with its whole ſurface, no part of it can ſink deeper than another. It is alſo well known, that its friction is the ſame whether its whole ſurface is preſſing, or only ſome parts of it. By experiments which I have made with great care, I have reaſon to conclude, that the friction of a plough ſole does not much exceed the fourth part of the preſſure which is acting on it. I have alſo made experiments with a wheel placed in the manner of Mr Moore's. I have found its reſiſtance to be very irregular, according as the ſoil was uniform or not. A

wheel of 16 inches diameter requires near $\frac{1}{4}$ of its weight or preſſure to draw it over an obſtacle one inch high, and near one half of its weight to draw it over an obſtacle two inches high. Many ſuch obſtacles occur in the bottom of a furrow; from hollows, eminencies, ſtones, ſoft places, and looſe mould, which tumbles in, and it would be but a moderate eſtimation to reckon them equivalent to an obſtacle of two inches high. The reſiſtance therefore to ſuch a wheel is nearly double the reſiſtance to a common ſole plate. I do not by this mean to aſſert, that the reſiſtance to Moore's plough is double of that of a common plough, becauſe I have obſerved already that the reſiſtance at the heel is but a ſmall part of the whole reſiſtance to

which the plough is expofed, and it is this refiftance alone upon which the wheel makes any change.

I will now add, that ufing of this wheel in place of a common fole, greatly hurts that fteadinefs of motion, which we have been at fo much pains to procure, and which is one of the greateft properties of a plough. For, as the wheel finks into a hollow, or goes over an eminence, the point of the fock muft be raifed or depreffed. Accordingly it is found, that when it is ufed without a carriage under the beam, the plough goes with a very hobbling motion, and although the beam-carriage prevents this in Mr Moore's plough, it muft be acknowledged, that the labour of the cattle muft be increafed on this account.

With

With reſpect to the wheel which performs the office of the land ſide, the ſame inconveniencies muſt attend it in a greater degree, becauſe, from its ſituation, it cannot be above nine inches diameter. Indeed, it cannot be nearly ſo big, without projecting too much to the right: it is, therefore, much more affected by any inequality of ſurface than the other wheel. The bad effects of theſe inequalities are more conſiderable on this wheel, for this additional reaſon, that the wheel itſelf is placed in a part of the plough where there is really a greater preſſure.

A plough of this conſtruction, but without wheels under the beam, has been tried in company with other ploughs of the common form, and it

was

was found to require at least a third more power to draw it. I did not, however, attribute the whole of this to the wheels, because the plough was defective in the construction of its other parts.

There is another wheeled plough which deserves to be taken notice of, because it has met with the approbation of the society in London, for the encouragement of arts and manufactures, and has a very great name, as the plough which is drawn by the least force possible. The make of the body of this plough is not very different from that of the Rotherham plough, from the point of the coulter and the sock backwards. It differs a little in the manner of framing, the left stilt being extend-

ed

ed forward, ſo as to ſerve in place of the ſheath. The mouldboard alſo is ſo contrived, that it may be ſet at different widths.

This plough has three wheels. One of them is placed under the fore end of the beam, which has a bend upwards at the place of the coulter, on purpoſe to give room for a wheel of two feet three inches high. The other two wheels are on an axle-tree fixed to the beam, a little behind the point of the coulter and ſock. One of theſe wheels treads upon the unploughed ground. The other is let down by means of a crank upon the axle, ſo as to go at the bottom of the furrow on the right ſide. The third wheel is fixed to the beam by a frame, which comes back as far as the

point

point of the coulter, where it is fixed to the beam. A part of the frame comes perpendicularly up from the centre of the wheel, and goes through the beam like a flider, fo that it can be fet at different heights. By this means the plough is tempered to any particular depth. Thus the plough becomes a fort of wheel carriage.

The view of the fociety in making experiments with this plough, was to difcover whether the whole amount of friction on a well conftructed plough was an inconvenience which was worth regarding. The refult of the experiments was, that it was not. The refult could not be otherwife; for the effect of thefe wheels was little more than carrying the weight of the plough itfelf.

One

One of the wheels, indeed, acts a little like the wheel in the sole of Mr Moore's plough, and has all its inconveniencies.

This disposition of the wheels is attended with other great inconveniencies. As two of the wheels are very near the point of the coulter and sock, whenever both, or one of them, are raised upon any eminence, the point of the plough must immediately rise, and the connecting parts are exposed to very great strains. When the wheels have got over the eminence, and would come down again, they are prevented, because the sock is now at a less depth than before, and must advance some space before it can regain its former depth. By this means the wheels are often kept from pressing on the surface,

while

while, at other times, they are moſt violently ſqueezed to it, ſo that the plough is neither regular in its depth, nor in the labour which it gives to the horſes, unleſs the ground be a ſmooth plane. Even in this caſe, the labour of the cattle is conſiderably increaſed, becauſe the two wheels, being ſo near the coulter and ſock, are violently ſqueezed into the ground. By thus ſinking into the ſoft earth, they require a force to draw them forward, nearly equal to what would draw them over an obſtacle half as high as the depth to which they ſink.

I have given this account of the wheeled plough, in order to ſhow, that beſides the other inconveniencies to which they are expoſed, they are not adapted

adapted for procuring the very advantages for which they are intended. The advantages alſo are but inconſiderable, and by no means equivalent to the great additional expence, to the riſque of going out of repair, and the trouble of keeping them in order. I might have ſaid, that they poſſeſs no advantages over the ſledge plough; for they cannot be uſed except in well dreſſed ground, free from ſtones. In ſuch ſoils, there is no uſe for them; for it appears that the principles upon which a plough operates, while it is performing its work in the manner required by the farmer, are ſo certain, that a plough may be made which will perform the work with hardly any attention on the part of the ploughman. Whether I

have ſucceeded in giving a conſtruction of a plough which is perfect in this reſpect, the reader muſt judge, or experience muſt determine. The intelligent reader muſt ſee that the thing is poſſible; and if ever it is done, the plough conſtructed in this manner muſt be preferable to all others, for cheapneſs, ſimplicity, eaſineſs of being kept in repair, and its capableneſs of being adapted in an inſtant to every change of ſoil which the ploughman can obſerve.

Here follows the deſcription of a plough which can turn the furrow to either ſide at pleaſure, and is therefore uſeful for ploughing along the ſides of ſteep hills, where the furrow muſt always be turned to the lower ſide. See fig. 23. Nos. 1. 2. 3. 4. 5.

No. 1.

No. 1. is a view of the frame part of the plough before the mouldboard is put on. The redd or curve of the beam cannot be leſs than is repreſented in the figure, otherwiſe it would not leave room from the motion of the coulter, which is all below it, as is repreſented in fig. 2. A much greater curve is hurtful, by reaſon of the weight of the plough being too high, becauſe this plough muſt always be leaning conſiderably to the land ſide.

The ſtilts may be made in four different ways. 1*ſt*. A half length of a ſtilt may be framed to the beam, and fixed to the ſheath and head, and the whole kept together by a bolt E F, as is repreſented in No. 1. To the part above the beam, two handles may be fixed by

three

three rungs. *2dly*, A piece of wood may be taken, which has a cast to the left hand, so that it will answer for the left handle, when it is framed to the beam, as already mentioned. To this may be spliced a handle of an equal cast to the opposite side. *3dly*, A piece of wood may be formed which has a natural fork, suited to this purpose. *4thly*, A piece of wood may be taken which has a proper cast for a stilt up and down, and of such toughness, that when it is sawn along the middle, near to the beam mortise, it will bear to be bent aside to the necessary width.

The sheath is about $1\frac{1}{8}$ inch thick by five inches broad. The head is three inches deep, by four inches broad. In framing of these parts together, they

are

are all placed in the direction of a line along the middle of the head and beam.

The left mouldboard is seen sideways in No. 2. QR being the fore edge, where the two mouldboards meet, and S T is the hindermost edge. The two mouldboards are seen from above in No. 3. which shows the angle which their upper edges make with each other. The fore edge of the mouldboard is also seen in No. 1. being represented by the dotted line G H. These mouldboards are mitred together before. The inside of the mitre is represented by K L in No. 1. They turn round an iron bolt D C No. 1. which goes through the beam and head. The bolt has a head at C, which is sunk into the head of the plough

plough, and it is ſcrewed at D, where there is a nut. This bolt paſſes through the ſolid wood of the mouldboard, through the mitre: therefore, before the mouldboards are faſtened together, a half round grove is made in each, and when they are joined, theſe groves make a round hole, as if made by an augre. The angle which the underſide of the mouldboard makes with the upper ſide, is about 18 degrees, both being ſtraight, ſee No. 6. where A C is the lower edge of the right hand mouldboard, and A B its upper ſide. The mouldboards may be formed to the regular twiſt, by means of the bevel, fig. 17. The angle between them at the ſole ſhould be the ſame with that made by the land ſide and mouldboard ſole of

of a common plough, which is about 15 degrees. Then the mouldboards will make an angle of about 15 degrees below, and 52 degrees above. In order to keep them at their proper angle, and to strengthen them against the pressure of the earth, which tends to force them together, they are secured below by a forked strap of iron of the proper angle, which has a hole through it for the mouldboard bolt D C No. 1. to pass through. This strap is nailed to the lower edge or sole of the mouldboards. They may also be secured by a rung between them, so placed as to pass free between the sheath and stilt. They are secured above by what I call the iron beam, represented separately in No. 5. and seen sideways at E Q T, No. 2.

This

This beam, No. 5. is formed to the proper angle E A F of 51 degrees, and has a hole at G, through which the upper part of the mouldboard bolt passes. The part A N projects forward, right with the middle of the angle E A F, formed by its sides, and has a square mortise at H, for receiving the upper part of the coulter, as is more distinctly seen in No. 2. The fore part N of this iron beam is formed into a point, for being received into the catch F E of No. 2. This iron beam between the coulter hole and the point of the mouldboards is two inches thick, and the end of the coulter which goes into the hole H is two inches by $\frac{7}{8}$.

There is also fixed on the upper edge of the mouldboards behind, an arch of

iron, repreſented by L M, No. 3. in the middle of which, at K, there is a ſocket, for receiving the handle K T N.

A B C of No. 3. and E F of No. 2. repreſent the catch which keeps the mouldboards in their proper poſition. This catch goes over the beam like an arch, and has a bolt D E through it, and through the beam, round which it turns upward and downward. The holes at A and C are for receiving the point of the iron beam, repreſented by E in No. 2. and by N in No. 5. The catch is made very ſtrong between theſe two holes and the bolt holes D and E No. 1. namely, about $\frac{7}{8}$ ſquare. The catch is made to keep its hold of the iron beam by means of a long ſpring, repreſented by C D in No. 2. and by

F B in No. 3. Its fore part is nailed to the beam; and as the ſpring acts upwards, it preſſes the arch of the catch upwards, and this keeps the hole A or C on the point of the iron beam. This catch is looſened from its hold by means of a ſtring or rope, which is faſtened to the top of the arch F, No. 2. and comes backward, through a ſtaple M on the beam, to the part L of the jointed handle.* By raiſing the end of the handle, the rope is drawn tight, and it pulls down the top of the arch of the catch, by which the other end E of the catch is drawn off from the point of the iron beam. The mouldboard being now ſhifted to either ſide, by puſhing the handle to the oppoſite ſide, the rope is then allowed to ſlacken, and the o-

ther

ther hole of the catch immediately falls on the point of the iron beam, and keeps it fast.

In order that these mouldboards may be able to shift to the proper angle, it is necessary that the lower part of the stilt, and the heel-piece at B, No 1. be reduced to the thickness of the sheath. In order to make this more effectual, and also to give that mouldboard, which is at the firm ground, some support from the head of the plough, the upper side of the head is sloped off for an inch down, as is represented by the line A B, No. 1. The lower edge of the mould-board is equally sloped off on the inside, so that when the plough is set, the land side mouldboard claps close with its chamfered edge to the chamfer of the

upper

upper ſide of the head, and is then ſupported by it, and all dirt or ſmall ſtones is by this means prevented from getting between them, and the mouldboard and head make one uniform ſurface, without any projection on that ſide for about ſix inches up.

The edge of the coulter muſt be ſet right in the middle of its thickneſs, but the back of the coulter muſt have a thickneſs equal to $\frac{1}{4}$ of its breadth. By this means, when the mouldboard is ſhifted to one ſide, that face of the coulter which is next the firm ground, will be fluſh with that ſide of the head, or will lie in the direction in which the plough is going, agreeable to the principles formerly laid down.

The

The lower part R, No. 2. of the fore edge of the mouldboard muſt always be kept cloſe to the upper ſide of the ſock. If it projects to either ſide, and a ſtone gets into the angle, the plough will be broken, or its motion will be prodigiouſly retarded: therefore, the upper ſide of the ſock muſt be made of a breadth proportioned to the ſhift of the mouldboard, at the place where the lower point of the mouldboard traverſes over it. This is repreſented in No. 4. where D is the centre of the motion of the mouldboards, and A is the fore point of them when the plough is turning the furrow to the left hand, and F is the place of it when the plough turns the furrow to the right hand. The breadth of the ſock A F will therefore

depend

depend on the width of the shift of the plough, and on the distance from the bolt D. In the dimensions represented in the figures, A F must be four inches, because the point of the mouldboard shifts two inches on each side of the middle line of the plough.

If the bolt, round which the mouldboards turn, were placed perpendicular, as at I C, No. 1. the upper surface of the sock, No. 4. should be quite flat. But when the bolt D C, No. 1. leans back above, the upper surface of the sock between A and F, and behind it a little, must be rounded a little above. Thus the point of the mouldboards will keep close to the back of the sock as the plough shifts.

While

While the point A, No. 4. ſhifts over to F 4 inches, the point G of the coulter ſhifts over to H 6 inches, ſo that in both poſitions of the plough, it is an inch without the point of the mouldboard, and better than half an inch without the land ſide of the head, which is a very proper poſition. If the fore edge of the coulter is parallel to the bolt D C, the upper end of the coulter will ſhift as much as the lower. If the edge of the coulter and bolt are narrower above than below, which is the caſe in the figures, the upper end of the coulter will ſhift leſs. This ſhift of the upper end of the coulter is repreſented in No. 5. where the line M G N is the middle line of the plough, I is the upper end of the coulter, when the plough turns the

the furrow to the left hand, and K is its place when the plough is turning the furrow to the right. This shift in the figures is 2½ inches on each side of the middle line, or 5 inches in all. At the same time, the upper point A of the fore edge of the mouldboard shifts 3 inches from A to L. This shifting of the upper and under parts both of the coulter and of the mouldboard edge depends, as has been already said, on the position of the bolt D C, and on the distance of these parts of the coulter and mouldboard from the corresponding parts of the bolt. Attention must be paid to these circumstances, in order that they may have always a proper position. The shifting of the fore point of the iron beam must regulate the distance

tance between the two holes of the catch.

It is neceſſary in this plough, that the horſes go all in the furrow. For, in ploughing along the ſide of a ſteep hill, a horſe cannot find footing on the unploughed land, but will be always ſliding into the furrow.

This circumſtance requires a bridle of a particular conſtruction, to allow the draught to be ſhifted at every turning of the plough. See No. 3.

QP is the bridle, 10 inches within from Q to P. It is ſtraight before, and without any notches. The horſe tree has a ring, which ſlides from ſide to ſide on the bridle. At Q and P are two rollers or ſheaves. A rope has its middle fixed to the ſliding ring, and the two ends are made to paſs through the

roller Q and P, and the two staples on the upper side of the beam, just before the catch bolt D E, and through another staple in the stilt G, just by the beam mortise. They then are made to pass through two other rollers on the upper side of the stilt handles at R and S, and then their ends are brought together, drawn tight, and tied together.

From this description of the plough, it is easy to see, without repeating what has been already said, how all the parts are shifted.

Figures 7 8 and 9 represent the parts of another shifting plough, which has been a good deal employed. P M, fig. 7. is a side view of the beam, A C D is the bridle, having holes in its fore part, for giving more or less hold. The bridle

dle turns in a bolt B C, which passes down through the beam. The tail C D comes a good way back, and has, on its upper side at D, a pin with a broad head, which takes hold of the end H of the iron beam H I L, which turns on a bolt K L, in the same manner with the iron beam of the other shifting plough.

A catch bolt G H goes down through the beam at G, and serves to fix the iron beam to the wooden beam, when the plough is shifted. This bolt is kept down by a spring F G. It is drawn up by G R N, which turns round a joint at R, and has a rope reaching from N to the ploughman's hand. When he pulls the rope N O, the point G of the catch rises, and raises the spring and bolt G H, and loosens the iron beam from the wooden beam.

Fig.

Fig. 8. is a view of the upper side of the same parts; C E D is the bridle, turning on the bolt at E L. M F G is the iron beam, turning on the bolt at G. In the fore part of this iron beam at D, there is a hole for receiving the broad headed pin, which is in the tail of the bridle at D. This hole is made oblong, to allow the pin to shift along it as the plough is shifted. The part L M is formed into the arch of a circle, of which the centre is G, and it has a hole at each extremity L and M for receiving the catch bolt. It has also a hole in the middle between L and M for the same purpose. In order to keep the arch L M close to the beam, so that the bolt G H, No. 7. may fall truly into the holes in the arch which are made

to receive it, there is a support for the iron beam, represented in fig. 9. B D C is this piece. The part B D goes thro' the beam, and is screwed or rivetted above at B. A tail sticks out at H, which is nailed to the under side of the beam. It passes thro' between the arch L M of fig. 8. and the arms. The part D C projects forward below the arch, and it has a hole at C, exactly below the hole thro' the beam, through which the catch bolt comes. When, therefore, the catch bolt has been drawn up, and the arch L M comes into such a position, that any of its holes comes exactly between the hole in the beam and the hole in the piece B D C, the catch bolt being let down, it goes through all the three holes, and keeps all fast together. When the plough

throws

throws the furrow to the left, the catch bolt is in the hole at N, and when it throws the furrow to the right, it is in the hole at L. The plough may alſo be employed to throw the furrow both ways, by putting the catch bolt into the middle hole of the arch L M.

The iron beam cannot ſhift any more than the open ſpace which is within the arch L M, becauſe, when it is put ſo much to one ſide, it is ſtopped from going farther by the pin B D of No. 9. ſtriking againſt one of the arms.

The hind part of this iron beam has got two tails, in the ſame manner as in the other ſhifting plough, by which it is fixed to the mouldboards, and all the other parts are made in the ſame manner.

Of

## I. Of Wheels in general.

To attempt to prove that a carriage is more eaſily drawn upon wheels than upon ſledges, would be an affront to the underſtanding of the reader.

But whether high or low wheels are fitteſt for the purpoſe has been a ſubject of diſpute, even among perſons of ſkill. Reaſon and experience, however, ſeem perfectly to agree in this, that wheels, whoſe centres are on a level with the moving power, will be eaſieſt drawn along a level plane, and that the higher a wheel is, it will more eaſily get over any obſtacle, if the moving power is not below its centre. It ſeems

to

to follow therefore, that carriages drawn by horſes or oxen ſhould have wheels whoſe centres have the height of the draught line, that is, of the ſhoulders of the horſes, or the yokes of the oxen. This is true, however, only in the caſe of a horizontal road. In going up a hill, the diſtance of the line of draught from the road is ſomewhat leſs, becauſe, when a man, or any other animal, is ſtanding upon the ſide of a ſlope, his height is inclined to the ſlope, although it is perpendicular to the horizon. As this is the ſituation in which it is of the greateſt importance to diminiſh the labour of the cattle, it follows, that the height of a wheel's centre ſhould be ſomewhat leſs than the height of the line of draught. But what the difference

difference ſhould be depends upon a great number of circumſtances, which thoſe who make uſe of wheel carriages ſhould be beſt acquainted with. Four feet eight inches is reckoned a very good height for a cart wheel, and has been thought preferable to any other. But the great loads which are drawn in the coal carts at Glaſgow, which go upon wheels above ſix feet high, and other inſtances of a like kind, ſhow that great advantages are to be gained by uſing the high wheels, and that the diſadvantage ariſing from the greater weight of the wheels may be diſregarded. The great inconvenience which attends the high wheels is the greater preſſure upon the cattle on going down hill, becauſe the ſupport which

the cattle can give in this caſe, is very low placed. But, even in this caſe, the inſtances above mentioned, ſhow that the height of wheels may be increaſed beyond the ordinary practice.

## II. *Of the Diſh or Cavity of Wheels.*

Suppoſe that a perſon totally unacquainted with the practice, were employed to make a cart. He would naturally make the axle ſtraight, and the arms of it without taper. He would ſet the ſpokes of the wheels at right angles to the axle, by which means they would alſo be perpendicular to a level road, and thereby give the moſt perfect ſupport to the carriage and its load. Such wheels would be flat, and their ſole or head would be parallel to the axle.

But

But experience has ſhown, that ſuch wheels are liable to great inconveniencies. When going in wet and dirty roads, all the mud taken up by the wheel comes down again upon the nave, and gets between it and the axle, and ſoon wears it prodigiouſly. Such a form of wheels alſo requires a great diſtance between them, and conſequently a great breadth of road, in order to give room for the cart body and loading. It is alſo found, that ſuch wheels bear hard upon the inner end of the axle arm below; and alſo, that the ſpokes are forced back in the mortices, and the wheels in time get a diſh or hollow on the ſide next the cart.

The reaſon of theſe two laſt inconveniencies is this: It is very ſeldom that the

the two wheels are exactly on the same level. When one of them is lower than the other, either by getting into a rut, or being on the lower side of the road, the greatest part of the load is upon that wheel. In this situation, the head of the wheel is not perpendicularly below the point of the nave, which is supported by the spoke. The spoke itself leans over, and if not of sufficient strength, would break inwards. It therefore bears hard upon the inner side of the mortice, and causes the nave to bear hard upon the inner end of the axle arm.

Experience has shown, that these inconveniencies may be greatly removed, by setting the spokes into the nave, so as to point outward a little. By this means the wheel gets what is called a

dish,

dish, and the ſpokes no longer form a flat ſurface. Let us now ſuppoſe, that two ſuch wheels are put upon an axle, whoſe arms have no taper. The wheels would be as wide above as below, and the ſpokes would never be perpendicular to the ground. Suppoſe now, that the two axle arms are bent downwards. This would make the wheels cloſer below, and wider above, and the bend of the axle may be ſuch, as that the ſpoke which reſts upon the ground will be perpendicular. This form of the wheels will remove ſome of the above mentioned inconveniencies.

The wheels being wide above, the mud which is carried up by them will not fall ſo much upon the nave, and there will be greater room for the body of

of the carriage and its loading. But one of the great inconveniencies ſtill remains. When one of the wheels is in a rut, the ſpoke which is then ſupporting the carriage is leaning outwards, and bears hard upon the inner end of its mortice, and cauſes the nave to bear hard upon the inner end of the axle arm. It is, therefore, found more expedient not to bend the axle ſo much as to bring the two ſpokes, whoſe ends are on the road, to be perpendicular to the horizon, or parallel to each other. They are made to be a little wider below than at the centre; by which means, when one wheel is in a rut, the ſpoke which is then ſupporting the carriage, may be perpendicular. It is even found neceſſary, that when the wheel is in this ſitu-

tion,

tion, the ſpoke ſhould be a little without the perpendicular below; for the chief jolts which the wheel receives are from the outſide, and when the ſpoke is ſet a little againſt the jolts, it is better able to reſiſt them. Experience ſhows, that, notwithſtanding all the diſh which has been given to wheels, they ſtill go from the face, or looſe their cavity when they fail. It might, therefore, be ſuppoſed, that it would be an advantage to give the wheels a ſtill greater diſh. But this is limited by other conſiderations. The ſpokes muſt be very hard driven into the nave, in order to have ſufficient ſtrength. They muſt not be very much tapered at the foot, otherways they would be apt to work looſe. This being the caſe, the ſpokes cannot be ſet very

very obliquely into the nave, becaufe the wood of the nave would then ftart up at the heel of the fpoke, when it is properly driven.

A difh or cavity of $3\frac{1}{2}$ inches may be given with fafety to wheels of 4 feet 8 inches diameter, and in general $\frac{3}{4}$ inch of difh may be allowed for every foot of diameter.

The fpokes fhould be fet fo far from the outer end of the nave, that a perpendicular from the fole to the under fide of the axle, may fall between an inch and two inches without the middle point between the bufhes. By this the preffure on the outer bufh will be fomewhat greater than on the inner, when the wheels are on a level. This fhould be fo. For the inner part of the axle

arm

arm being much bigger than the outer, it has more friction, and therefore ſhould have leſs preſſure. Alſo, every ſinking of the wheel below the level of the other, cauſes it to preſs harder on the inner buſh. This poſition of the ſpokes remedies both theſe inconveniencies.

There are ſtill ſome perſons of experience, who have propoſed that the wheel ſhould be made without any diſh, and they propoſe to remedy the inconvenience which ariſes from an unequal preſſure upon the outer and inner ends of the axle arm, by placing the ſpokes, not in the middle of the nave, but towards the outer extremity. This will only remove the inconveniency to a certain degree, and it ſtill leaves the other defects which have been already

mentioned without any remedy. The experiment has been tried, and it has been found, that the axle arm is ſtill much worn at the inner end, and that the wheels are much weaker, and ſooner fail, getting a diſh inwards. In ſhort, the diſhing of wheels, which was not a natural thought, has either been found by accident, or has been invented by ſome perſon of great ingenuity, and the courſe of uniform experience has fully confirmed its advantages.

### III. *Of the Length of the Naves.*

Too ſhort an axle arm has too little power to guide the wheel in a ſteady direction, unleſs very tightly fitted into the buſhes, and too long a nave is inconvenient,

convenient, both on account of its bulk, and of the dirt which it is apt to carry. 12 inches or thereabouts seems a very convenient length for a nave, exclusive of the depth of the pan in the ends.

## IV. *Of the Taper of the Bushes.*

It is found necessary to line the inside of the nave hole with iron. This is done by driving two iron rings, called bushes, into the opposite ends of the hole. The axle arm is made to fit exactly the inside of the bushes. The wideness of a bush therefore always determines the size of the axle upon which it turns, and the smaller the bush is, the less will be the friction. The wideness must be such as suits the axle required

red for the carriage. The ſtrain upon the axle arm is chiefly at the inſide buſh, and wooden axles generally require an inner buſh of $5\frac{1}{4}$ or $5\frac{1}{2}$ inches for ordinary carriages.

When ſpeaking of the diſh of wheels in the ſecond ſection, we ſuppoſed the axle arm to be without any taper. In order, therefore, that the ſupporting ſpokes may ſtand perpendicular to the ground, or nearly ſo, it is neceſſary to bend the axle arms downwards. But this would be attended with a very great inconvenience. When the carriage is going upon a level road, the wheel would be continually ſliding in upon the axle, and would preſs hard upon the ſhoulder. As this is the place where dirt is moſt apt to get in, the friction would

would be prodigiously increased, and the bushes and axle would be very much heated and worn. This inconvenience would be still more sensibly felt upon that wheel which gets into a rut, and bears the greatest part of the load.

This inconvenience is remedied by the very simple contrivance of tapering the axle arm. The intention, therefore, of this contrivance being to hinder the dished wheels from pressing in upon the shoulder of the axle, the manner of executing it must be taken from these principles. In the *first* place then, the under surface of the axle arm, which rests on the bushes, must be level. If it be higher at the inner end, they will slide in and press on the shoulders. If it be higher at the outer end, they will

slide

slide out, and press on the linch pins. In the *second* place, the spoke which touches the ground, or which is supporting the carriage, must either be perpendicular, or must lean a little inward above, and outward below. These two conditions will determine the quantity of taper which must be given to the axle and bushes.

In the *first* place, let us suppose, that the supporting spoke must stand perpendicular. In fig. 1. let L K B A represent the taper hole through the nave. The lower side A B must be level. Let E be the point of the sole which touches the ground. Draw E D perpendicular to A B. Let Q O be the centre line of the hole. This will be the line round which the wheel really turns. E D will

will cut this line in C. Let G be the uppermost point of the wheel, exactly opposite to E. Draw G C. For the same reason, that E D is perpendicular to A B, G F will be perpendicular to L K, the upper side of the nave hole. Draw G E, cutting the line of the centre in H. Then C H is the true dish of the wheel. Let the lines L K and A B meet in I. Then, because the two triangles E C H and I C D have a common angle at C, and equal angles at H and D, the angles at E and I are equal. Therefore the half taper of the axle and bushes is just the same *per* foot as the real dish of the wheels, and we may use the following proportion. As the half diameter of the wheel is to its real dish, so is the length of the nave to

half

half the taper of the bushes, or to half the difference of the width of the inner and outer bushes.

On the other hand, the real dish of the wheels may be gathered from the taper of the axle and bushes. For if we draw B R parallel to the centre line O Q, then Q R will be equal to O B, the half width of the outer bush, and R A will be half the difference of the width of the inner and outer bushes, or will be half the taper of the bushes corresponding to the length of the nave, which must be counted on the centre line Q O. Now B R is equal to O Q. Also, B R is to R A as E H is to H C. That is, the length of the nave is to the half taper of the bushes, as the half diameter of the wheel is to the real dish.

Then

Thus, from the dish of a wheel already made, we can chuse a pair of bushes which shall answer it, and taper the axle accordingly; and from the bushes already cast, we can give the wheel the proper dish. A pair of bushes, of which the inner is $5\frac{1}{4}$ inches diameter, and the outer $3\frac{1}{4}$, are found to answer very well, and require a real dish of $2\frac{1}{3}$ inches for a wheel of four feet eight inches diameter.

In the *next* place, let it be supposed, that the standing spokes should spread out a little below, which is thought most proper. This may be done either by increasing the dish of the wheel, or diminishing the taper of the bushes. Thus, if the taper of the bushes be what we have now recommended, that is two

inches, and alſo the diſh of the wheels be $3\frac{1}{2}$ inches, the ſpokes will ſpread $1\frac{1}{6}$ inch on each ſide below.

The ſpokes may ſpread ſtill more, by ſetting them more obliquely.

It is moſt convenient to have both buſhes made to one taper. This will make the axle arm of one taper both at the inner and outer end. This however is not abſolutely neceſſary, provided that the taper of each part of the axle arm is made to ſuit the buſh which is to turn on it.

## V. *Of fitting in the Buſhes.*

This muſt be very exactly done, otherwiſe the wheels can never run well.

The

The firſt circumſtance to be attended to, is the ſetting them fair, that is, ſo that the centre line of the two buſhes may make one ſtraight line, which ſhould be the centre line of the whole eye of the wheel, or nave hole.

In fig. 2. let A B be the centre line of the eye of a wheel. It is plain, that if the inner buſh c d e f be ſet more down at C than at e, it will be nearer the centre line at d than at f, and will grate upon the axle arm at d, which will both obſtruct the motion, and exhauſt the greaſe; and if the outer buſh be more ſet down at k than at h, it will be nearer the centre line at i than at g, which will have the ſame effect. Their centre lines will not, in this caſe, fall in with A B, but will ſtand at A a

and

and B b. Great care muſt therefore be taken to avoid this, and make them ſtand fair. If both the buſhes have one taper, their inſide ſhould run ſtraight with the lines c h and e k.

The *ſecond* thing to be taken care of is, that the centre line of the buſhes may be perpendicular to the face of the wheel, without which the wheel cannot turn true on the axle arm. This may be diſcovered by turning the wheel round an axle arm which fits it, and holding a ſteady mark to ſome place to the face of the ring or felloes. This will touch the face all round as it turns, if the centre line is perpendicular to the face. If it does not, there is an error, which, if not helped, will cauſe a falſe motion of the wheel, and make

crooked

crooked ruts in the road, equal to the diſtance of the different parts of the face from the ſteady mark above mentioned.

## VI. *Of the Sole of a Wheel.*

This ſhould be ſo made as to preſs fair on the road, eſpecially if the ſole or tread of the wheel is broad. When the axle is ſtraight or level on its under ſide, the ſole ſhould make the ſame angle with the face which the taper of the buſhes makes with their centre line, except what is to be allowed for the declivity of the road. Therefore uſe this proportion. As the length of the nave is to half the taper of the buſhes, ſo is the breadth of the ſole to the quantity which

which it ſhould be above the ſquare. Thus, if the length of the nave be 12 inches, the taper of the buſhes two inches, and the breadth of the ſole three inches, $12 : 2 = 3 : \frac{1}{4}$, and the inner edge of the ſole ſhould be $\frac{1}{4}$ of an inch above the ſquare with the face of the wheel.

## VII. *Of fitting in the Axles.*

In order to do this properly, we muſt know, 1*ſt*, what is called by the workman the diſh of the wheels, which is very different from what I have called the real diſh, and the methods for finding it. 2*dly*, The way of finding the length of axle beds, which will anſwer to any given wideneſs on the road, the axle being ſtraight below, in order

to

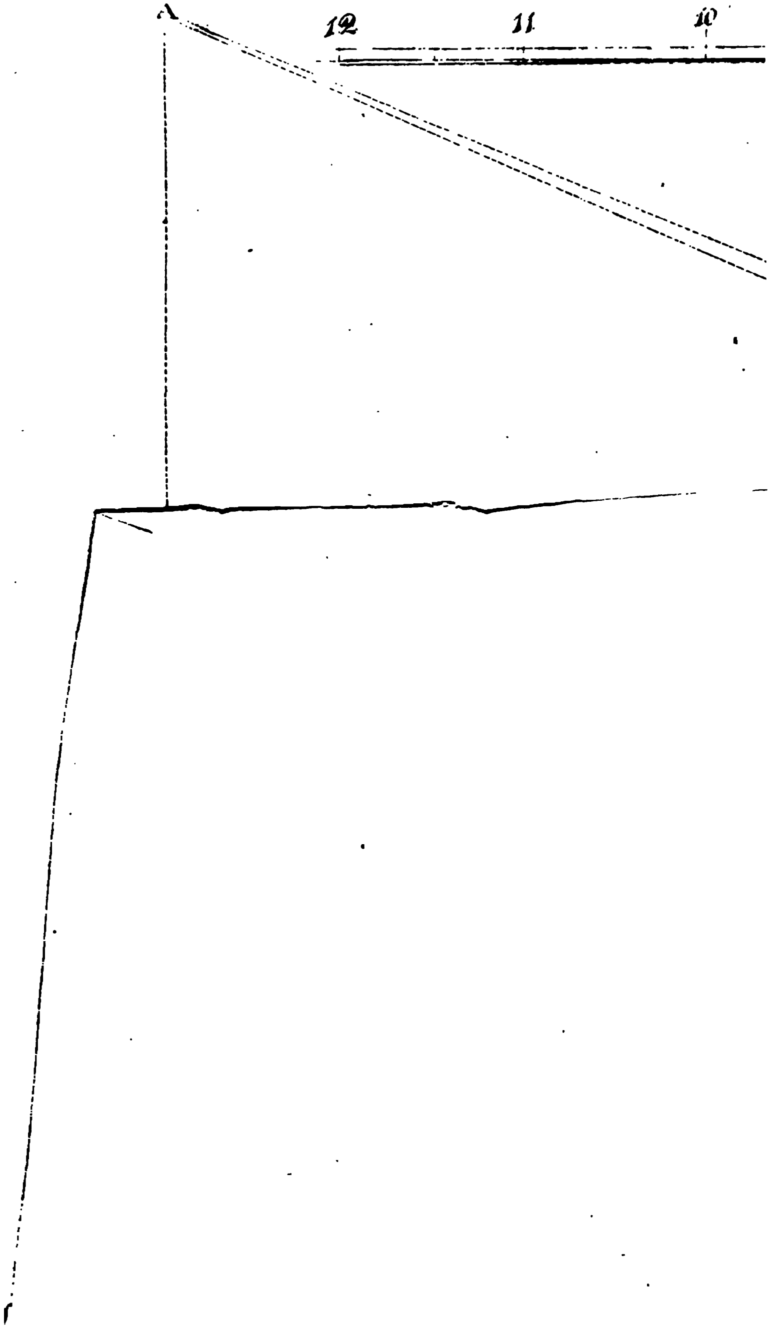
to find what length will anſwer for any given hollow, and what hollow will anſwer to any given length of an axle bed. When every thing needful has been calculated, the wood for the axle muſt be prepared, and ſet out (as the workmen call it) with great exactneſs, that is, the lines muſt be truly drawn, which direct us for working the axle, ſo as to make the arms fit the buſhes, and the wheels run right on the road, and the work muſt be truly executed according to theſe lines. When nearly done, it will be proper for the workman to try whether the wheels gather inwards equally on both ſides, both below and before. This he may do, by applying a line or ruler diagonal wiſe, acroſs from the under part of the right

right wheel to the upper part of the left wheel, and then from the under part of the left wheel to the upper part of the right wheel. If the wheels are properly ſet, theſe two trials ſhould give the ſame diſtance on the line or ruler.

Thus, ſuppoſing a c, fig. 3. and b d two wheels gathering below, between c and d. If b c is found ſhorter than a d, then either b is too far in, or a is too far out. Then the diſtance a b and c d ſhould be meaſured, to know if the gather is as much as is required.

*N. B.* This gather will always be equal to twice the real diſh of the wheels. If it is too little, a muſt be brought a little in. If it is too much, throw out b. If juſt right, a muſt be brought in, and b thrown out equally.

Of


A
12
11
10

VIII. *Of finding the Dish of the Wheel.*

What the workmen find most convenient to consider as the dish of a wheel is considerably different from what I have called the real dish.

Figure 4. represents a wheel seen edge-ways, and standing on the level ground, with its sole o a. The line h i, which is the lower side of the axle arm, is supposed to be level, or parallel to o a. The line m h f is parallel to the face of the wheel b a, and i k is parallel to the centre line A B. H e is perpendicular to the ground. Now, e o, the distance of this perpendicular from the inner side of the sole o, is called the dish of the wheel by the workmen. It

is plain, that the diſtance of the point e, from the like point correſponding to the other wheel, is the diſtance between the ſhoulders of the axle, or the length of the axle bed.

This being attended to, the two following methods may be taken for finding the diſh of a wheel.

1. By a ſquare and rule.

Let a b c d (fig. 3. No. 2.) repreſent the ring of a wheel, g h i a ſquare. The ſtock h i is applied through the eye of the wheel to the buſhes. The blade is applied to the inner end of the nave, and reaches as far up as the ring of the wheel. Then a rule, d e f, being held ſquare over it, will ſhow the diſtance between

between the inside of the square and the sole of the wheel, which is the dish sought, allowance being made for the distance of the square from the bush, occasioned by the depth of the inner pan, if there be any.

2. By calculation.

Let a straight ruler c d (fig. 4.) be applied to the face of a wheel, as near the nave as possible. Let a straight rod, l m n, be put thro' between the spokes, square on c d. This will show the distance m n between the face of the wheel and the inner end of the nave. Then say, as this distance is to half the taper of the bushes, so is the height of the lower side of the axle arm (supposed

level)

level) to a fourth quantity. This muſt be added to the breadth of the ſole, and the ſum muſt be taken from m n. The remainder is the diſh required; for it is plain, that f a is very nearly equal to i k, which is equal to m n; and that ik : k h :: h e : e f; and alſo, that e o is the difference between f a and the ſum of f e and o a.

Thus, if the diſtance of the lower ſide of the axle from the ground be two feet, or 24 inches, and the taper of the buſhes two inches, and the diſtance of the inner end of the nave, from the face of the wheel, be 12 inches, and the breadth of the tread be $2\frac{1}{2}$ inches, we have 12 : 1 :: 24 : 2, which is f e. Then f e and o a make $4\frac{1}{2}$ inches. This taken from 12 inches, leaves $7\frac{1}{2}$ for the

diſh

dish of the wheel, or one foot three inches for two wheels.

This calculation may be done by the sliding rule, which is much used by cart wrights. Set 12 to 24, and then 1 will stand opposite to 2 for f e, and proceed as before.

## IX. *To find the Length of the Axle Bed.*

This is the distance between the inner ends of the two naves.

1. When the axle arms are straight below, from the proposed wideness between the wheels within on the road, take the dish of both wheels, the remainder is the length of the axle bed.

*Example.*

*Example.*

| | | |
|---|---|---|
| Wideneſs on the road within, c f, (fig. 5.) - - | 4 | 6 |
| Diſh of both wheels, c d + e f | 1 | 3 |
| Length of axle bed - | 3 | 3 |

The truth of this rule is plain, by inſpecting fig. 5. where A B is the axle, c f the wideneſs within on the road, c d and e f the diſh of the wheel, and a b the length of the axle bed.

2. When the axle is hollow below.

This is often the caſe, becauſe the bed of an axle is ſometimes confined to

to a certain length, eſpecially ſuch as have iron arms, whether they are fixed to waggons or carts. In ſuch caſes, they muſt be made hollow below, or the arm muſt be laid into the bed, with a bend downwards, in order to bring the wheels to a right gather, or make them run at a right diſtance on the road. This is alſo ſometimes neceſſary, in order to make the tread of the wheel preſs fair on the road. Theſe circumſtances give riſe to two queſtions or problems.

1. Having given a certain length of axle bed, and a certain wideneſs on the road, to find the degree of hollow, that is to ſay, how far the under ſide of the axle arm ſhould be below the ſtraight, at the out end of the nave.

*Rule.*

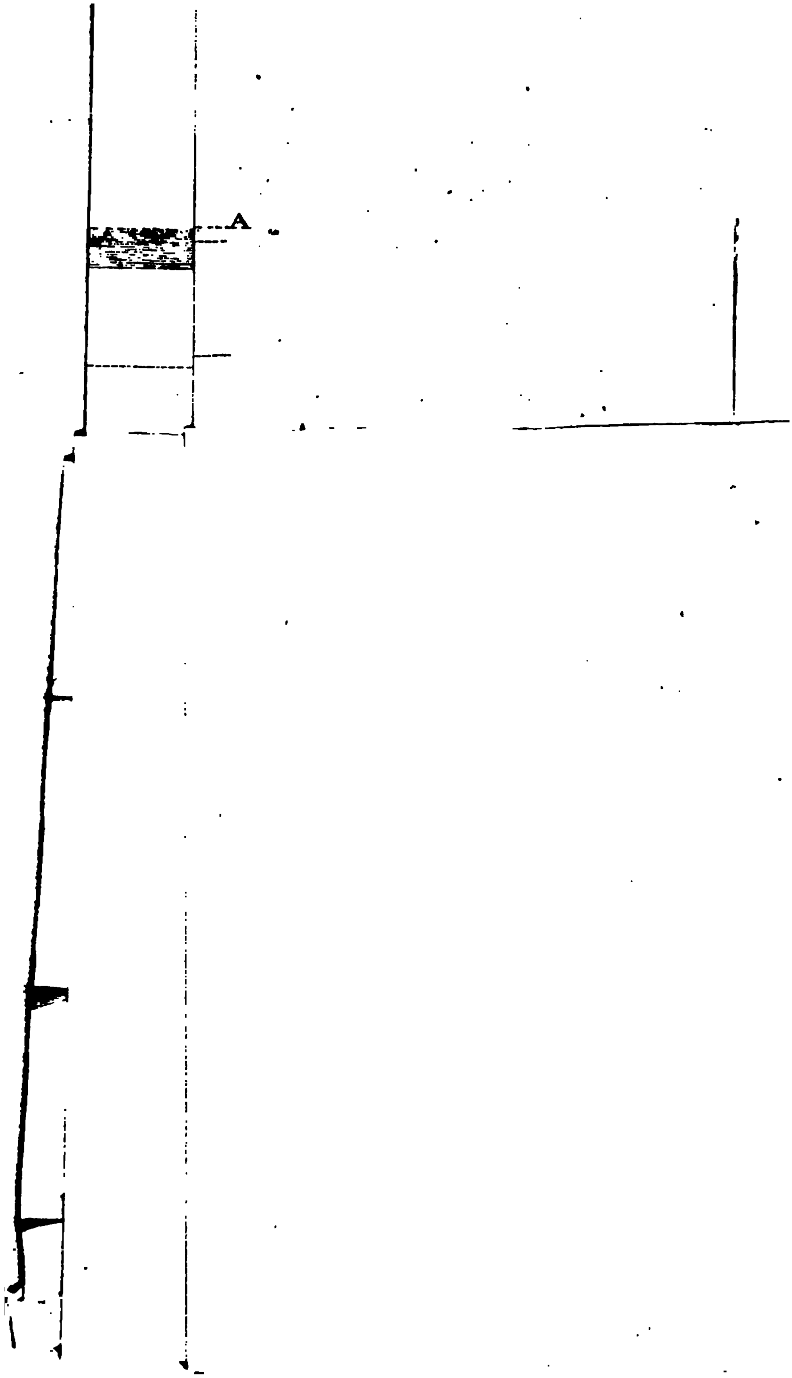
*Rule.*

Find the length of the bed, which will give the wheels the required wideneſs of the road, when the arms are ſtraight below. Take half the difference between the given length of bed, and the length then found. Then ſay, as the height of the under ſide of the ſtraight axle from the ground is to this half difference, ſo is the length of the arm to the hollow required.

*Example.*

Suppoſe the given length of bed is three feet ſix inches, and the given wideneſs on the road four feet ſix inches,

and


A

and the wheels to have the dimenſions of the laſt example, namely, one foot three inches of diſh, *&c.* and the height of the under ſide of the axle from the ground two feet, or 24 inches, and the length of the arm 12 inches, then the length of the bed will be three feet three inches by the laſt rule. The difference is three inches, half of which is $1\frac{1}{2}$ inches. Then 24 is to $1\frac{1}{2}$ as 12 to $\frac{3}{4}$ of an inch, which is the hollow required.

The reaſon of this operation is very eaſily underſtood.

Let A B (fig. 6.) be the given length of bed, F K the given wideneſs on the road, and let C D be the length of bed which would give the wheels that wideneſs on the road, when the axle is

 ſtraight

ſtraight below. Let C E be the length of the arm. Draw C L perpendicular to the horizon. Then L F is the diſh of the wheels. Now, ſuppoſe the axle bent down to the poſition C M. The line C F will take the poſition C G, in ſuch a manner, that the angle E C F will be equal to the angle M C G, and therefore the angle E C M will be equal to the angle F C G. Draw E M perpendicular to E C, and F G perpendicular to C F, and G H perpendicular to F K. It is eaſy to ſee that C E : E M : : C F : F G, and that C E : E M : : C L : F H. Now, F H is half the quantity by which the diſtance between the wheels is diminiſhed, by bending down the axle from C E to C M. If, therefore, A C be made equal to F H,

and

and A O be made parallel to C M, the wheel placed on the bent arm, P B A O, will have the same wideness on the road as when on the straight axle Q E. Therefore A C is really the half difference between the two axle beds, when E M is the hollow or bend of the axle. Therefore the rule given is just.

*N. B.* It is not strictly just, because C G is not equal to C F, but the difference of A C or E M from the truth does not amount to the 500th part of an inch.

Quest. Given a certain hollow E M, and a certain wideness F K on the road, to find A B the length of the axle bed.

*Rule.*

Find, as before, the length of bed C D for an axle ſtraight below. Then ſay, as the length of arm C E is to the given hollow E M, ſo is the height of the lower ſide of the ſtraight axle from the ground C L to a fourth number, which will be A C. Twice this, added to the ſtraight axle bed, will give the hollow axle bed.

*Example.*

Suppoſe $\frac{3}{4}$ of hollow, and four feet ſix inches on the road are given for the wheels, which we have ſo often mentioned, then $12 : \frac{3}{4} :: 24 : 1\frac{1}{2} = A\ C.$

Now,

Now, the double of this is three inches, and C D is three feet three inches, therefore A B is three feet six inches.

The reaſon of this is evident from what has been ſaid already.

In the foregoing calculation, the height of the under ſide of a ſtraight axle from the ground was always one of the numbers to be worked with. In order to find this, conſider figure 4. Thus it is plain that h f is equal to i a, which is half the breadth of the face of the wheel, deducting half the width of the buſh at i, even with the face of the wheel. Meaſure i h along the buſh, i k was found in the way formerly directed. Then we have i h : i k : : h f : h e, the height from the ground. I may here obſerve, that h e will hardly ever differ

$\frac{1}{8}$ of

$\frac{4}{8}$ of an inch from h f or i a, ſo that it is hardly neceſſary to make a calculation for it.

I conclude this part of the ſubject by obſerving, that if the taper of one axle be leſs than that of another, the axle whoſe taper is ſmalleſt will require to be farther bent down, in order to give the ſame pair of wheels the ſame gather below, or to put the wheels in the ſame poſition; and the additional bend that muſt be given for this purpoſe is juſt equal to one half of the difference of the two tapers.

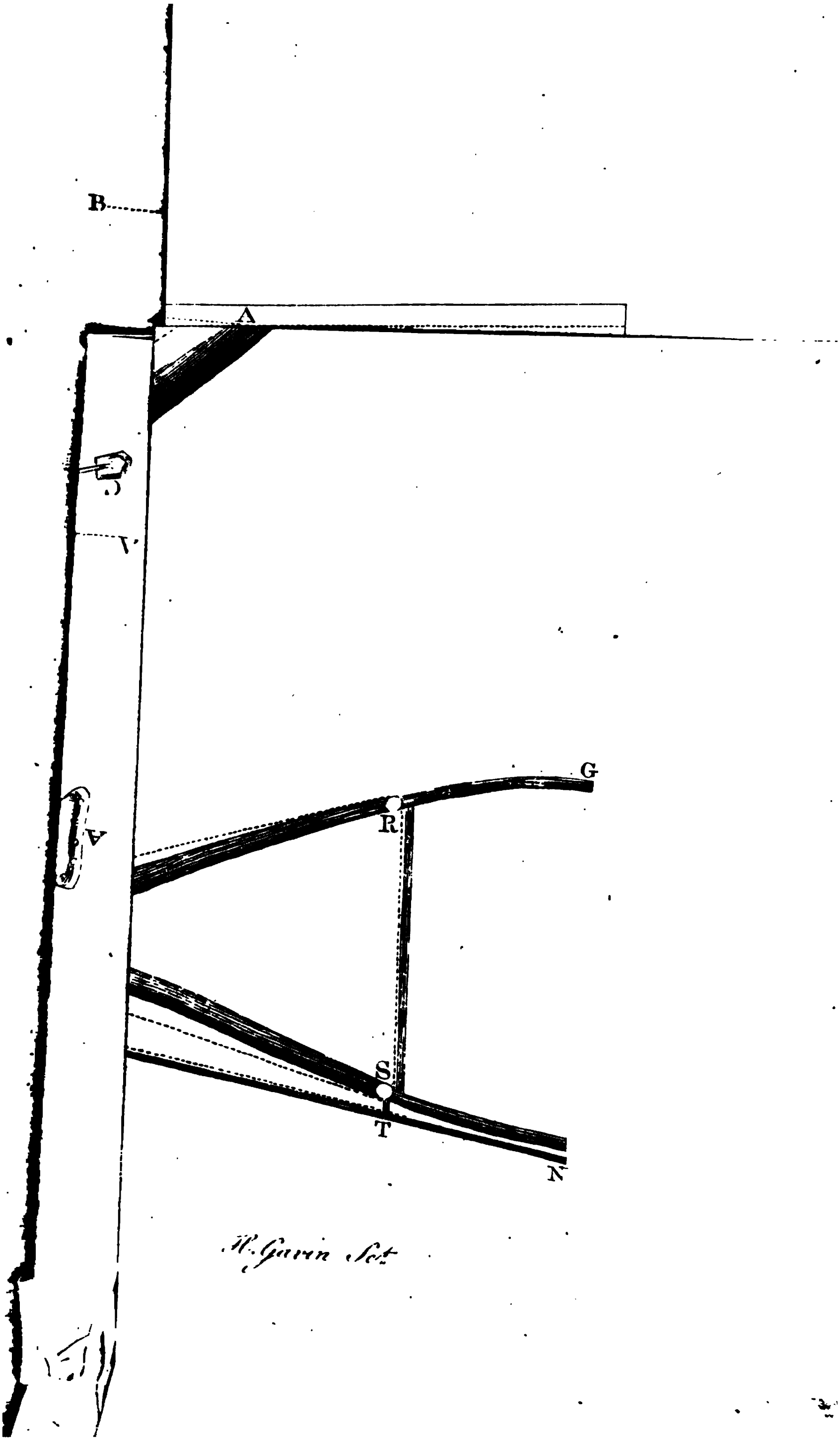
Let the axle A B D C, (fig. 7.) be ſtraight below, and have two inches of taper. Let L I be the centre line, and K I a horizontal line. Let A P be the face of the wheel, and L Q a perpendicular

cular from the centre of the outer bush. It is plain that K L is equal to half the taper, or difference between the width of the bushes. It is also plain, that I L is to L K as L Q to Q P, which is half the gather of that wheel. Again, let E F H G (fig. 8.) be another axle, straight below, with only one inch of taper. M O will, in like manner, be half the taper, and half of K L. S R will therefore be half of P Q. If, now, we make S T equal to P Q, we must bend the arm to the position H V with its lower side, so that G V may be equal to M O. This will bring down the centre O as much further as it is already below the level M N, and then the position of the face O T will be the same with that of the face L P, and, consequently,

quently, both wheels will have the ſame gather below.

## X. *Of the gathering of the Wheels forward.*

It is found, by experience, that wheels run better when they are gathered a little forward, or incline a little inward towards the foreſide of the axle. The taper of the axle arm is the cauſe of this. The wheel being preſſed forward by the arm, it muſt be forced outward by the taper, unleſs it be balanced by an inclination inward. The more, therefore, that the arm is tapered, and the leſs that the wheels are gathered below, the more gather forward will be required. About an inch and



B
A
V
A
G
R
S
T
N
W. Gavin Sct.

an half of gather forward is found, by experience, to anſwer for wheels of four feet eight inches high, with buſhes of two inches taper, and an axle ſtraight below.

The rule for bringing wheels to their gather is this:

The axle being made ſtraight on the under ſide, a line muſt be drawn along the middle of the under ſide. Then the length of the arm, and of the bed, being all marked out, ſet off $\frac{3}{16}$ of an inch, or a little leſs, towards the fore ſide of the axle, at the out heads, and take the points thus ſet off for the centres from which the out ends are to be ſquared.

But that every perſon may be ſatisfyed as to the method of finding theſe diſtan-

ces, the following proportions will anſwer to every caſe.

As the half height of the wheel is to the fourth part of the intended gather, ſo make the length of the arm to the diſtance ſought.

This proportion may be thus demonſtrated from fig. 9.

Let a b c d repreſent the under ſide of an axle, n e f r a line drawn along the middle of it, n o the diſtance ſet forward at one out head, and r o the diſtance ſet forward at the other. Then, ſince the centre line of the axle muſt correſpond with the centre line of the buſhes, and the face of the wheel cuts theſe lines at right angles, if the centres of the out heads were continued in the ſtraight line in n and r, the face of the wheels

wheels would cut that line at right angles, at the lines h t and m u. But when the centre of the out heads are placed in o and o, the faces of the wheels will cut the lines e o and f o at right angles, and therefore the angle o e n and h i k are equal; so also the angles f i t and u i v are equal, and o f r and l i m are equal. Therefore, as i h, the half height of the wheel, is to h k, a fourth of the gather, (that is a fourth of the difference between h l and f v) so is e n, the length of the arm, to n o, the distance sought, and so of the other end, because i l : l m : : f r : r o.

## XI. *Of the Manner of placing the Carriage on the Wheels.*

Let a b c d (fig. 10.) represent the body of a carriage, and suppose it placed on a pair of wheels, which require no packing, the half height of the wheel being n p. Suppose it again placed on a pair of wheels, whose half height is o p, so as to require a packing to raise it to the same height with the other. The height of the packing will then be equal to n o. In a level road this will make no difference of weight on the horse's back. But if the carriage should be going down a road, making an angle with the horizon of about 15 degrees, it will make a considerable difference, as

may

may be ſeen by the figure. For ſuppoſe i k to repreſent ſuch a declining road. Then, if a perpendicular to the horizon is raiſed to the centre of the high wheel, it will cut the carriage at e g, whereas a perpendicular paſſing through the centre of the low wheels will cut it at f h. From this it is evident, that the higher that any carriage is raiſed above the centre of the wheels, the greater weight will, in ſuch a caſe, be thrown on the back of the horſe. And, in going down, the horſe will have too much weight, and, in going up, too little.

The higher any carriage is thus raiſed, and the more any road declines, the greater will be the inconveniency, ariſing from the additional weight which

is thrown upon the horſe's back, when going down hill, and his having too little weight on his back, when going up hill. It will be ſome remedy if the ſhafts or limbers of the cart be raiſed in going down hill, and lowered in going up hill; which may be done by altering ſome links of the back band.

## *Of fixing the Axle on the Carriage.*

After an axle has been properly fitted into the wheels, ſpecial care muſt be taken, that it be not turned out of its right poſition by the manner in which it is fixed to the carriage. Axles are ſometimes fixed to the body of the carriage, and ſometimes to the ſhafts or limbers, the body lying looſe above them. In whatever manner the axle is

fixed,

fixed, it muſt be kept, while working, in the poſition for which it was drawn. Therefore when the axle is fixed to the body of the carriage, and that body is ſo placed as to be level when going upon level ground, the axle muſt be fixed with the plane of its upper ſide parallel to the body of the carriage.

When the axle is fitted to the ſhafts, it muſt be conſidered how much higher the ſhafts will be at the back band than at the axle, when the carriage is going upon level ground. This may be known from the height of the wheels, and the height of the horſe, (ſee fig. 10.) Let a c e repreſent one of the ſhafts, a f the height at the back band, and b c d a level line paſſing through the upper ſide of the axle. It is plain, that to keep

keep the axle in the right poſition, its upper face muſt be kept in the line b c d. If it be merely applied to the outer ſide of the ſhaft a c e, the wheels will be made to have too much gather forward.

The right ſlope to be given to the axle or ſhaft, where they are fitted together, may be found by the following proportion. As the length of the ſhaft from the fore ſide of the axle to the back band, is to the difference between the height at the axle, and at the back band, ſo is the breadth of the axle on its upper ſide, to the depth to which it muſt be let into the ſhaft, at the hind ſide more than at the fore ſide. For a c is to a b, as c d is to d e.

From


*Fig. 3 No. 2.*

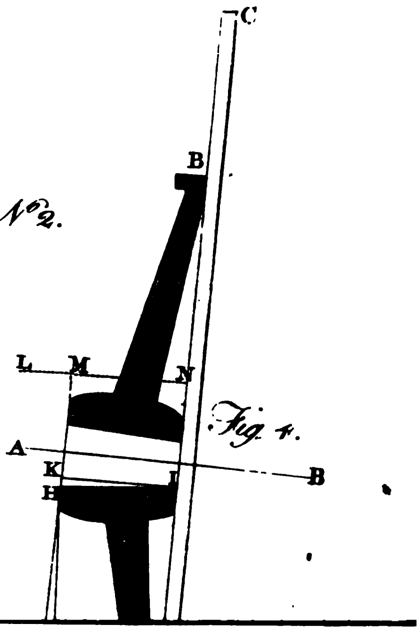
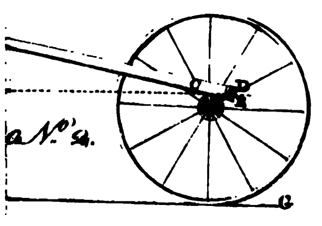



*Fig. 4.*




*a No. 4.*

nr

From this it is alſo plain, that the gather forward may eaſily be either increaſed or diminiſhed, by the manner in which the axle is fixed on, and that a proportionable difference will, at the ſame time be made on the gather below, or wideneſs on the road.

Maſters and drivers ſhould be careful to keep the ſhafts always about the ſame height, by the manner of yoking the horſes, becauſe ſome alteration will be made by every change. The buyer of a cart ſhould get from the maker a note of the difference between the height of the wheels, and the height of the back band, to which the cart was adjuſted, or the workman ſhould be enjoined to adjuſt the cart in this reſpect in the manner which the buyer may think

moſt ſuitable to his horſes. Any alteration occaſioned by the change of horſes, muſt be corrected by altering the length of the back band, ſo as to bring the ſhafts to that height to which they were adjuſted by the maker.

XIII. *Some Remarks on the Obſervations made by Mr Jacob on the bending of the Axle-arms downward.*

He ſays, that the univerſality of this practice would make one apt to ſuſpect, that there muſt have been ſome better reaſon for it than ſeems at preſent readily to be given by artificers.

It muſt be allowed, that experience and facts are always ſuperior to theoretical reaſonings, and that every theory

con-

contradicted by theſe is to be rejected, however plauſible it may appear. But, in this caſe, theory and experience perfectly agree, as will appear by conſidering a little the neceſſary conſequences of the conical form of the axle arms.

Let a b c, (fig. 11.) repreſent any heavy body preſſing upon d e f, d f being parallel to the horizon. Then it is plain, that d e f will be preſſed from d to f. Therefore an axle, tapered off on the under ſide, preſſes the buſh in this manner, and muſt cauſe the wheel to fly out.

Suppoſe again a heavy body, as A B (fig. 12.) preſſing on another C D, and that the ſurface, by which they join is horizontal, it is plain, that C D will be preſſed ſtraight downwards, without

any

any tendency towards C or D. Therefore an axle which is ſtraight below will not preſs the wheel either outward or inward, in ſo far as it is acted on by no other cauſe than the downward preſſure.

Again, ſuppoſe a b (fig. 13.) to be an axle arm bending downwards, and c d to be the part of the buſh on which it preſſes. It is plain, that the wheels will be preſſed inwards by this form of the axle.

I muſt now obſerve, that the axle arm exerts another preſſure upon the buſhes, beſides that which is directly downwards. For, by the draught of the horſes, it muſt alſo preſs upon the fore part of the buſh. This forward preſſure is but very ſmall in compariſon with the downward preſſure, when

the

Fig. 11.

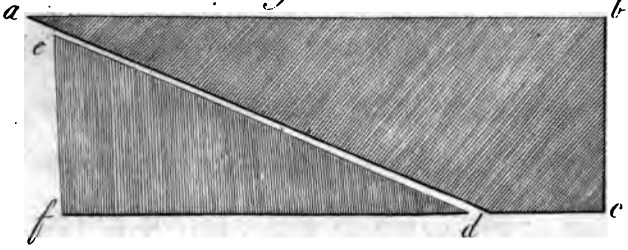



Fig. 12.

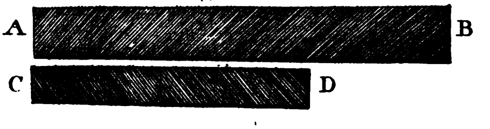
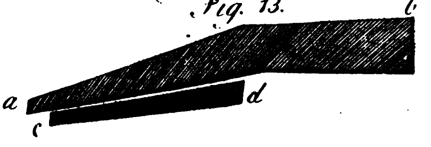



Fig. 13.



the carriage is going upon perfectly e-ven road, being no more than what is sufficient for overcoming the friction of the wheels. But every obstacle over which the wheels are to be driven, must increase this pressure upon the fore side of the bush. From this it is evident, that when an axle is straight below, the taper of the arms on the fore side will cause the wheels to press outwards, unless this pressure is balanced by some other. This may be done, either by bending the axle downwards, which will produce a pressure inwards, sufficient to balance this pressure outwards, of which we have now been speaking.

Or, it may be more perfectly done, by keeping the axle straight below, and bending it a little forwards, in the man-

ner directed in ſect. X. It is this circumſtance which gives occaſion to the gather of the wheels forward; and Mr Jacob is miſtaken, when he makes the bend of the arms, or gather of the wheels, to depend wholly upon, or be regulated by, the diſh or cavity of the wheels; and when he alledges that the diſh of a wheel neceſſarily requires a bend in the axle arm, to give it a motion ſtraight forward. Whatever the diſh of a wheel is, the face of it will always be perpendicularly cut by the centre line of the buſhes, if the wheel be truly made, and truly buſhed. It is therefore the taper of the arm, and not the cavity of the wheels, which is the immediate cauſe of that outward preſſure, which makes it neceſſary to bend

the

the arms either downward or forward. Mr Jacob is indeed ſo far in the right in his aſſertion, as a diſh of the wheel requires a taper of the arm, in order to gain thoſe advantages which are propoſed by the diſh.

But diſhed wheels *may* be uſed with cylindrical arms, and in this caſe the arms muſt neither be bent downwards nor forwards; for, if they were, the wheels would preſs violently inwards.

*F I N I S.*

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